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

Greater Wellington Regional Council (Flood Protection)

December 2016

MWH

BUILDING A BETTER WORLD

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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 a 4.8 km length of the Wainuiomata River, in the urban reach between XS 1530 and XS 1050, from the footbridge near the Hine Road car park downstream to Leonard Wood Park ("the application area").

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 the Wainuiomata River 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 Wainuiomata River originates in a native forest catchment of the south western Rimutaka Ranges, and flows southwest for a distance of approximately 35km, eventually discharging into Cook Strait east of Bearing Head. The Wainuiomata catchment shares a drainage divide with the Orongorongo catchment where elevations reach 800m in altitude. The catchment has a total area of 134 km^2, and has a predominantly greywacke hard-sedimentary geology, with a narrow thread of alluvial material along the valley floor. While the upper catchment is steep the river bed gradient is fairly uniform downstream of the Wainuiomata Water Treatment Plant, dropping 5m per km in the upper part of the Wainuiomata Valley, then flattening to 2m per km over the last few km above the coast.

The Wainuiomata River supports a moderately diverse fish fauna including the threatened (Nationally Vulnerable) lamprey and seven fish species considered to be at risk (Declining). Brown trout are found throughout the river system and constitute a valued trout fishery. The Wainuiomata River mouth has been scheduled as a signficant bird habitat in Wellington region's Proposed Natural Resource Plan, however the river mouth is located 18km downstream of the application area. With the exception of the mouth, the river does not provide suitable habitat for shorebird nesting birds; the remaining bird species likely to be found near the river are all relatively common and widespread in the surrounding landscape.

GWRC proposes that the full 'tool box' of flood protection activities as described in the Code should be available for use in the Wainuiomata River application area. 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 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. More recently a study conducted in the Hutt River at Belmont shows that bed disturbance over a 220mm 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 swift riffles. This could

have been improved if the channel realignment had been based on creation of a meander pattern (which it was not) and reconstruction of some channel complexity had been incorporated into the works.

The potential effects of larger scale works, for instance where mechanical disturbance of the river bed extends over river lengths 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 the EMP proposes a tiered 'event' monitoring approach, with increasing monitoring effort required for larger scale work 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. However the level of flood protection activity likely to occur in the Wainuiomata River is low by comparison with other rivers in the Wellington region and, accordingly, the potential for cumulative adverse effects is assessed as low. It is proposed 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 for the river over time.

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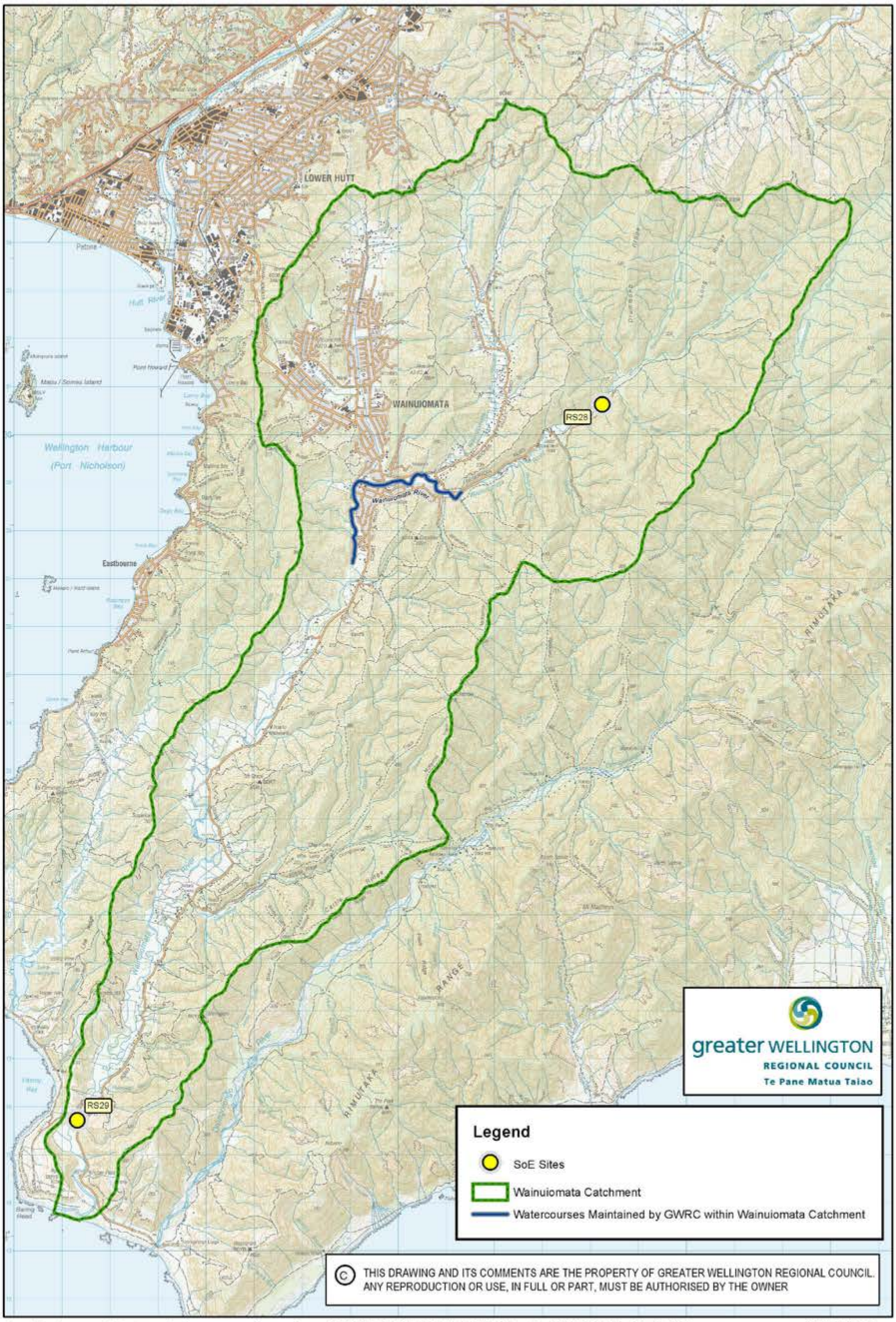
1 Introduction

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 4.8 km length of the Wainuiomata River, in the urban reach between XS 1530 and XS 1050, from the footbridge near the Hine Road car park downstream to Leonard Wood Park (refer Figure 1-1). Consent will be sought for 35 years.

The new consents are intended to replace existing consents that currently allow for flood protection activities on the Wainuiomata River. 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 the Wainuiomata River application area 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.



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File ref : Wainuiomata Catchment.mxd

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A4 Scale : 1:100,000

Figure 1 - 1 : WAINUIOMATA CATCHMENT

Indicating SoE Sites & Watercourses Maintained by GWRC

Drawn : P.cook
Date : 8 Aug 2013

2 Information Sources

Information on the water quality and biology of the Wainuiomata River and other relevant watercourses, has 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 (2015)	Habitat quality, water quality, periphyton and macroinvertebrates	Four sites on the Wainuiomata River within the application area	River survey in April 2015
Cameron (2015)	Habitat quality, water quality and fish	Three sites on the Hutt River	Before-After-Upstream-Control assessment of FP channel re-alignment works
Death & Death (2013)	Habitat quality, deposited sediment, periphyton macroinvertebrates and fish	Three sites on each of 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 Otaki River application area	Database accessed August 2015 + Trent Bell, unpublished data
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	Two SOE sites on the Wainuiomata River system	January 2004 to March 2015
GWRC maps	Application area, GWRC assets, RSoE sites, inanga spawning areas, riparian vegetation, NCI reaches	Entire application area	
New Zealand Freshwater Fish Database (NZFFD)	Fish	42 sites within the Wainuiomata River catchment	Data 1960 to 2015
McArthur (2015)	Comment on birds of Wainuiomata River upstream the Wainuiomata Estuary	Wainuiomata River	
McArthur, Robertson, Adams and Small (2015)	Birds	Wellington Region	Habitats of significance for indigenous 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	Two SOE sites on the Wainuiomata River	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 Wainuiomata River in a 4.8 km length of the Wainuiomata River, in the urban reach between XS 1530 and XS 1050, from the footbridge near the Hine Road car park downstream to Leonard Wood Park (refer Figure 1-1). A detailed aerial view of the application area in the Wainuiomata River is shown on Figures 3-1, 3-2 and a Map Series in Appendix A.

3.1 Wainuiomata River

3.1.1 Physical Characteristics

The Wainuiomata River originates in a native forest catchment of the south western Rimutaka Ranges, and flows southwest for a distance of approximately 35km, eventually discharging into Cook Strait east of Bearing Head. The Wainuiomata catchment shares a drainage divide with the Orongorongo catchment where elevations reach 800m in altitude. The catchment has a total area of 134 km^2, and has a predominantly greywacke hard-sedimentary geology, with a narrow thread of alluvial material along the valley floor. While the upper catchment is steep the river bed gradient is fairly uniform downstream of the Wainuiomata Water Treatment Plant, dropping 5m per km in the upper part of the Wainuiomata Valley, then flattening to 2m per km over the last few km above the coast.

The main tributaries of the Wainuiomata River are Skull Gully Creek, Sinclair Creek, George Creek, Wainuiomata-iti Stream, Black Creek and Catchpool Stream. The upper catchment is reserved for water supply and retains indigenous forest cover. Water is taken at two locations in the water supply area by 'run of the river' intake galleries, one on the main-stem of the upper river and the other on Georges Creek. Two decommissioned water supply dams are located on the upper river. Although neither is now used for water supply, the lower dam continues to form a large impoundment, which has been developed as a wetland. Downstream of the water supply area the river enters the long narrow Wainuiomata Valley, bounded by the Rimutaka Ranges to the east and the Eastbourne foothills to the west. Land use includes plantation forestry, low productivity pasture, scrub and urban Wainiuomata.

GWRC maintains two state of the environment river monitoring sites (RSoE) on the Wainuiomata River, one at Manuka Track within the forested upper catchment and a second on the lower River, approximately 3km upstream of coast. The Manuka Track site is approximately 4km upstream of the reach managed by GWRC Flood Protection (the application area), while the lower site is approximately 16km downstream of the application area. Details of river characteristics at the RSOE sites are included in Table 3-1. Habitat grades for the 2 RSoE sites and for 3 additional sites established within the application area (Cameron, 2015) 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*	*Horticulture*	*Pasture (high prod.)*	*Pasture (low prod.)*	*Urban (%)*	*Other (%)*
RS28	@ Manuka Track	Reference	excellent	99.9	0.0	0.0	0.0	0.0	0.0	0.0
RS29	@ White Bridge	Impacted	fair	79.6	3.7	0.0	2.9	7.5	6.2	0.1

Table 3-2: Habitat scores for SOE sites assessed in summer/autumn 2014 (from Heath, *et al*,2014), and at four sites within the application area (from Cameron, 2015)

Site no.	*Site name*	*Fine sediment*	*Invert. Habitat*	*Fish cover*	*Hydraulic hetergen-eity*	*Bank stability*	*Bank veg.*	*Riparian buffer*	*Riparian shade*	*Channel alteration*	*Total habitat score (of 220)*
RS28	@ Manuka Track	18	40	38	20	20	18.5	19.5	19	18	211
W1	@ Main Road Bridge	10	22	22	12	16	14	14	8	17	135
W2	@ Leonard Wood Park	12	24	22	8	16	12	16	8	17	135
W3	DS Wainui storm tank	12	24	20	10	16	12	16	8	17	135
RS29	@ White Bridge	19	30	16	13	13	6	4.5	1	16	118.5

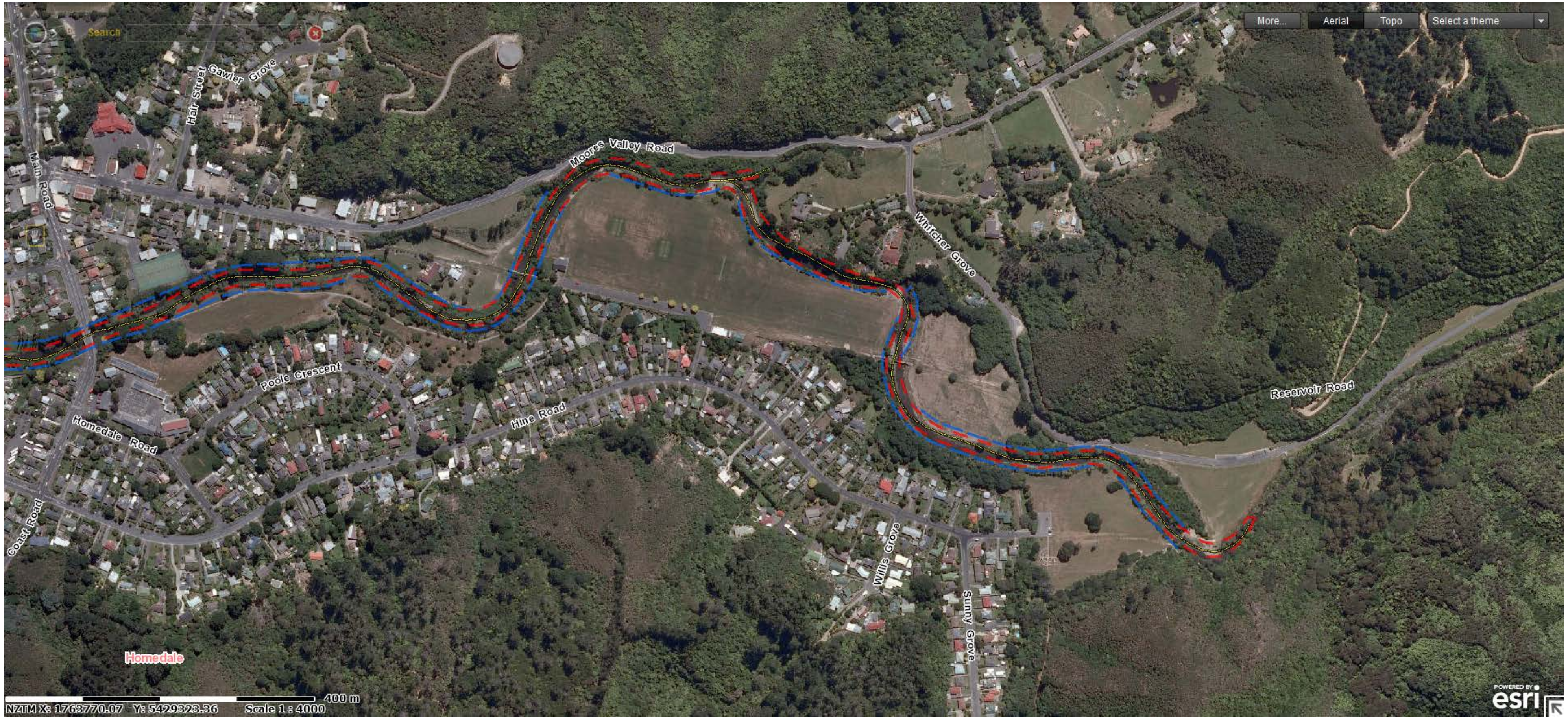

Figure 3-1: View of Wainuiomata application area (upper reach) showing design channel (red dash) and buffer zone (blue dash)

Figure 3-2: View of Wainuiomata application area (lower reach) showing design channel (red dash) and buffer zone (blue dash) and monitoring sites W1, W2 and W3 (from Cameron, 2015)

3.1.1 Wainuioimata River mouth

The Wainuiomata River mouth is located 18 km downstream of the river reach managed by GWRC Flood Protection. For much of the time the lower Wainuiomata River is ponded behind a gravel bar, which is built up during southerly storms. At times of low flow the river seeps through the gravels while at higher flows it overtops the bar forming a channel to the sea. Taylor and Kelly (2001) noted that the grasses growing beside the river upstream of the bar would not tolerate a high degree of saltwater exposure, indicating minimal saltwater intrusion into the river. The river mouth has been scheduled as a 'significant bird habitat' in Wellington Region's Proposed Natural Resources Plan (refer Section 3.1.9)

3.1.2 Water Quality

Surface water quality is routinely monitored by GWRC at the Manuka Track and White bridge RSoE sites on the Wainuiomata River. The Manuka Track site is approximately 4km upstream of the reach managed by GWRC Flood Protection, while the lower site is approximately 16km downstream of the managed reach (see Figure 1-1).

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 3-3. WQI grades for the year to June 2014 for RSoE sites located upstream and downstream of the application area are shown in Table 3-4 and water quality results for the five year period from January 2010 to March 2015 are summarised in Table 3-5.

The annual monitoring report for the year to June 2014 (Heath, *et al*, 2014) graded both sites as having "good" water quality; both sites having exceeded the trigger value for dissolved reactive phosphorus (DRP). In the case of RS28 which is an un-impacted reference site, elevated DRP appears to be a natural phenomenon, while in the lower-river additional DRP contributions are derived from urban and agricultural land use activities. These sites were ranked 21st and 25th, respectively, out of the 55 RSoE sites monitored in the Wellington Region for the year to June 2014. Median water quality at the RSoE sites at times when the river flow is less than median are summarised in Table 3-6. These results are relevant to the extent that in-river flood protection works are most likely to be undertaken during moderate to low flows. The low flow results were lower in respect of nitrogen but were otherwise very similar to the 'all flow' results.

Results of selected variables at sites RS28 and RS29 are summarised by annual boxplot for the years 2004 to 2015 to show trends over time (Appendix B). A Mann-Kendall Trend Test identified the following trends ($p<0.05$ and rate of change >1% per year):

- Increasing trend at RS28 for water temperature, pH, DRP and TP;
- Decreasing trend at RS28 for dissolved oxygen (%sat); and
- Increasing trend at RS29 for water temperature, pH and visual clarity.

Table 3-3: 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 (ºC)	≤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 3-4: Water Quality Index grades for RSoE sites upstream sites upstream and downstream of the application area, 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
RS28	@ Manuka Track	Good	21	✓	✓	✓	✓	✓	×
RS29	@ White Bridge	Good	25	✓	✓	✓	✓	✓	×

Table 3-5: Summary of GWRC monthly water quality data at Wainuiomata River RSoE sites sampled monthly between Jan 2010 and March 2015 (n=67). Median values that did not meet a guideline are shown in bold font.

Determinand	*Wainuiomata R.*@Manuka Track *(RS28)* *(upstream of application area)*			*Wainuiomata R.*@White Bridge *(RS29)* *(downstream of the application area)*			*Guideline value*
	median	*min*	*max*	*median*	*min*	*max*	
Water temp. (ºC)	10.5	5.69	15.8	13.2	7.8	20.7	≤19
DO (%saturation)	99.5	75.4	110.2	106	77	140	≥80
pH	7.27	6.21	7.64	7.34	6.65	8.97	6.5-9.0
Visual clarity (m)	2.38	0.35	5.42	1.48	0.27	3.30	≥1.6
Turbidity (NTU)	1.07	0.46	14.1	1.81	0.72	18.8	≤5.6
Suspended solids (mg/L)	<1	<1	19	<1	<1	14	--
Conductivity (µS/cm)	108	83	124	139	116	160	--
TOC (mg/L)	2.10	0.25	11.9	1.9	<1	3.8	--
NNN (mg/L)	0.074	0.018	0.280	0.166	<0.002	0.530	≤0.444
Ammoniacal N (mg/L)	<0.005	<0.005	0.011	<0.005	<0.005	0.079	≤0.021
Total N (mg/L)	0.150	0.055	0.670	0.290	0.055	1.120	≤0.614
DRP (mg/L)	0.011	<0.002	0.019	0.012	<0.005	0.028	≤0.010
Total P (mg/L)	0.014	0.009	0.940	0.018	0.008	0.064	≤0.033
E. coli (cfu/100ml)	6	<1	220	90	6	7,400	≤550

Table 3-6: Median water quality values at Otaki 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	*Wainuiomata R.*@Manuka Track *(RS28)*	*Wainuiomata R.*@White Bridge *(RS29)*	*Guideline value*
Water temp. (°C)	12.2	15.9	≤19
DO (%saturation)	99.2	95.8	≥80
pH	7.42	7.51	6.5-9.0
Visual clarity (m)	2.71	1.39	≥1.6
Turbidity (NTU)	0.63	2.05	≤5.6
Suspended solids (mg/L)	<1	1.85	--
Conductivity (µS/cm)	109	149	--
TOC (mg/L)	1.56	1.65	--
NNN (mg/L)	0.072	0.037	≤0.444
Ammoniacal N (mg/L)	<0.005	0.010	≤0.021
Total N (mg/L)	0.131	0.175	≤0.614
DRP (mg/L)	0.013	0.014	≤0.010
Total P (mg/L)	0.018	0.025	≤0.033
E. coli (cfu/100ml)	<4	68	≤550

3.1.3 Periphyton

GWRC monitors periphyton cover and biomass at RSoE monitoring sites RS28 and RS29 on the Wainuiomata 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.

These data sets are compared against the New Zealand periphyton guideline values summarised in Table 3-7. The results of periphyton biomass monitoring for the years to June 2010, 2011, 2012, 2013 and 2014 are summarised in Table 3-8. Monthly observations of filamentous and mat forming periphyton covering for the same period are summarised in Table 3-9.

Table 3-7: MfE guidelines used to assess periphyton stream bed cover and biomass (Biggs, 2000)

Instream value	Periphyton cover (%cover)		Periphyton biomass Chlorophyll a (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, the upstream reference site at Manuka Track complied with the MfE guidelines for periphyton biomass, 'filamentous algae' %cover, 'mat algae' %cover and cyanobacteria %cover on all sampling occasions. Over the same five year period the downstream site at White Bridge complied with the periphyton biomass guideline on only 1 out of 5 annual surveys, and complied with the guidelines for 'filamentous algae' %cover, 'mat algae' %cover and cyanobacteria %cover on 48 of 50, 50 of 50, and 6 of 7 surveys, respectively. These results show that excessive periphyton growth rarely occurs in the Wainuiomata River upstream reference site, but regularly occurs in the lower river. These results are consistent with the downstream increase in urban and agricultural land use, increased nutrient inputs and much reduced riparian vegetation in the lower river.

Table 3-8: Summary of streambed peripyton biomass at RSoE sites in the Otaki River application area from 2009 to 2014 (after Perrie *et al,* 2011; Perrie and Conwell, 2013; 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*
RS28	*Wainuiomata River@ Manuka Track*	10.2	1.4	4.35	8.14	9.28
RS29	*Wainuiomata River@ White Bridge*	236.3	78.6	108.5	41.29	50.7

Table 3-9: 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 for the years to June 2010, 2011, 2012, 2013 and 2014 (after Perrie & 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	RS28	*Wainuiomata R.@ Manuka Track*	12	0	0	1	0	nt	nt	nt
	RS29	*Wainuiomata R.@ White Bridge*	12	19	0	43	0	nt	nt	nt
2011	RS28	*Wainuiomata R.@ Manuka Track*	10	0	0	0	0	nt	nt	nt
	RS29	*Wainuiomata R.@ White Bridge*	10	4	0	8	0	nt	nt	nt
2012	RS28	*Wainuiomata R.@ Manuka Track*	10	0	0	0	0	nt	nt	nt
	RS29	*Wainuiomata R.@ White Bridge*	11	15	0	14	0	nt	nt	nt
2013	RS28	*Wainuiomata R.@ Manuka Track*	12	0	0	1	0	nt	nt	nt
	RS29	*Wainuiomata R.@ White Bridge*	11	50	2	32	0	nt	nt	nt
2014	RS28	*Wainuiomata R.@ Manuka Track*	12	4	0	4	0	2	0	0
	RS29	*Wainuiomata R.@ White Bridge*	7	30	1	41	0	34	1	0

Nt = not tested

3.1.4 Macrophytes

Observations from bankside inspections of the Wainuiomata River channel within the water supply catchment, downstream of Main Road Bridge and at Leonard Wood Park, 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.).

3.1.5 Riparian Vegetation

A almost pristine native vegetation cover has been retained within the GWRC water supply catchment, however, virtually all of the indigenous vegetation has disappeared from the river banks downstream of the water supply area. Within the application area the riparian edge vegetation is highly modified and has few indigenous elements. The majority of riparian edge vegetation within the application area is planted willows. Of the 9.6km of total river bank length within the application area, it is estimated that 5.6km (59%) has been planted with willows as vegetative bank protection. Scattered bushes of shrubby weeds such as blackberry, gorse and wattle are common and a variety of exotic tree species are present on the river banks.

3.1.6 Macroinvertebrate communities

GWRC undertakes annual RSoE monitoring of macroinvertebrate communities at the Manuka Track upstream reference site (RS28) and White Bridge (RS29) on the lower reaches of the Wainuiomata River. Neither site is located within the Wainuiomata River application area, which is limited to a 4.8km length in the urban reach between the Hine Road carpark and Leonard Wood Park. An additional survey of macroinvertebrate communities was conducted by MWH at three sites within the application area during April 2015 (Cameron, 2015). Macroinvertebrate abundance results from the February 2014 RSoE sampling round and the 2015 MWH survey are included in Appendix C. These results together with predictions from the FENZ database[1] were used to describe the core macroinvertebrate communities of the Wainuiomata River (Table 3-10). Macroinvertebrate composition by relative abundance is illustrated in Figure 3-3 while macroinvertebrate metric scores for the period 2010 to 2014 are summarised in Table 3-11.

The Wainuiomata River upstream reference site (RS28) is located in an indigenous forest catchment upstream of the application area. The river at this location supports a diverse macroinvertebrate fauna dominated by sensitive EPT[2] taxa, which make up 75% of individuals and 63% of recorded taxa. The mayfly *Deleatidium* is the dominant taxa being 3 to 4 times more abundant than the next most abundant

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

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

species, which typically include the caddisflies *Aoteapsyche* and *Olinga*, the mayfly *Coloburiscus* and the riffle beetle Elmidae*.* Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores indicate “excellent” quality class in the upper river reflecting the nearly 100% indigenous forest land cover and an absence of urban or agricultural development.

At site W1, within the application area, the indigenous forest has disappeared and the river is influenced by the agricultural area of Moores Valley and the urban area of Homedale. The land-use differences between site RS28 and W1 are accompanied by a marked change in macroinvertebate community composition. The abundance of *Deleatidium* is much reduced (although the abundance of mayfly *Austroclima* is increased), dominance has shifted to the caddisfly *Aoteapsyche* and the mollusc *Potamopyrgus*, and the abundance of two winged flies such as *Maoridiamesa* and the Orthoclad midges is increased. The community at W1 is tolerant of moderate nutrient enrichment and increased periphyton biomass. MCI and QMCI scores for site W1 indicate a ‘fair’ to ‘good’ invertebrate quality class, compared with ‘excellent’ at the upstream reference site.

Wainuiomata River sites W2 and W3 are subject to similar influences as W1, but they receive run-off from a much larger urban area; Wainuiomata township, via Black Creek. The invertebrate communities at W2 and W3 are, nevertheless, little different from that found at W1, being dominated by *Aoteapsyche* and *Potamopyrgus*, constituting a ‘tolerant’ invertebrate community. Site RS29, located approximately 16km downstream of the application area, has a similar a macroinvertebrate community composition to that recorded at sites W1 to W3, although the relative abundance of two winged flies (Diptera) is somewhat higher and caddisflies (Trichoptera) lower.

Table 3-10: Wainuiomata 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)*
Wainuiomata R.@ Manuka Track (RS28)	Upstream of application area Indigenous forest 99.9% Pasture 0.0% Urban 0.0%	*Deleatidium>Elmidae>Olinga>Aoteapsyche>Coloburiscus (Deleatidium>Coloburiscus>Austroperla>Zelandoperla>Aoteapsyche>Olinga)*
Wainuiomata R. at Main Road Bridge (W1 – MWH)	Within application area	*Aoteapsyche>Potamopyrgus>Maoridiamesa>Orthocladiinae>Austroclima (Deleatidium>Coloburiscus>Aoteapsyche>Olinga>Potamopyrgus)*
Wainuiomata R. at Leonard Wood Park (W2 – MWH)	Within application area	*Aoteapsyche>Potamopyrgus>Maoridiamesa>Orthocladiinae>Elmidae (Deleatidium>Coloburiscus>Aoteapsyche>Olinga>Potamopyrgus)*
Wainuiomata R. downstream of Leonard Wood Park (W3 – MWH)	Within application area	*Aoteapsyche>Potamopyrgus>Orthocladiinae>Tanytarsini>Elmidae (Deleatidium>Coloburiscus>Aoteapsyche>Olinga>Potamopyrgus)*
Wainuiomata R.@ White Bridge (RS29)	Downstream of application area Indigenous forest 79.6% Pasture 10.4% Urban 6.2%	*Orthocladiinae>Aoteapsyche>Austroclima>Potamopyrgus>Tanytarsini (Deleatidium>Elmidae>Aoteapsyche>Aphrophila>Olinga>Beraeoptera)*

Table 3-11: Mean macroinvertebrate metric scores (and standard deviation) at Wainuiomata River RSoE sites based on GWRC data collected annually in 2010, 2011, 2012, 2013 and 2014, and MWH data for 2015). 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*	*%EPT indiv.*
RS28	*Wainuiomata R.@ Manuka Track*	5	138 (3.65) (excellent)	7.32 (0.317) (excellent)	21.1 (3.11)	21.2 (3.11)	62.5 (5.16)	74.7 (5.48)
W1	Main Road Bridge	4	109 (6.04) (good)	4.23 (0.061) (fair)	18.3 (5.85)	9.5 (4.04)	50.9 (8.98)	47.3 (25.3)
W2	*Leonard Wood Park*	4	104 (4.65) (good)	4.34 (0.246) (fair)	18.8 (2.99)	8.8 (1.71)	46.7 (4.71)	54.9 (4.73)
W3	*Downstream Leonard Wood Park*	4	104 (2.43) (good)	4.59 (0.124) (fair)	17.75 (1.89)	8.78 (1.26)	49.2 (2.72)	48.1 (9.23)
RS29	*Wainuiomata R.@ White Bridge*	5	104 (4.81) (good)	4.56 (0.280) (fair)	24.4 (3.98)	10 (1.23)	41.4 (4.27)	53.2 (8.89)

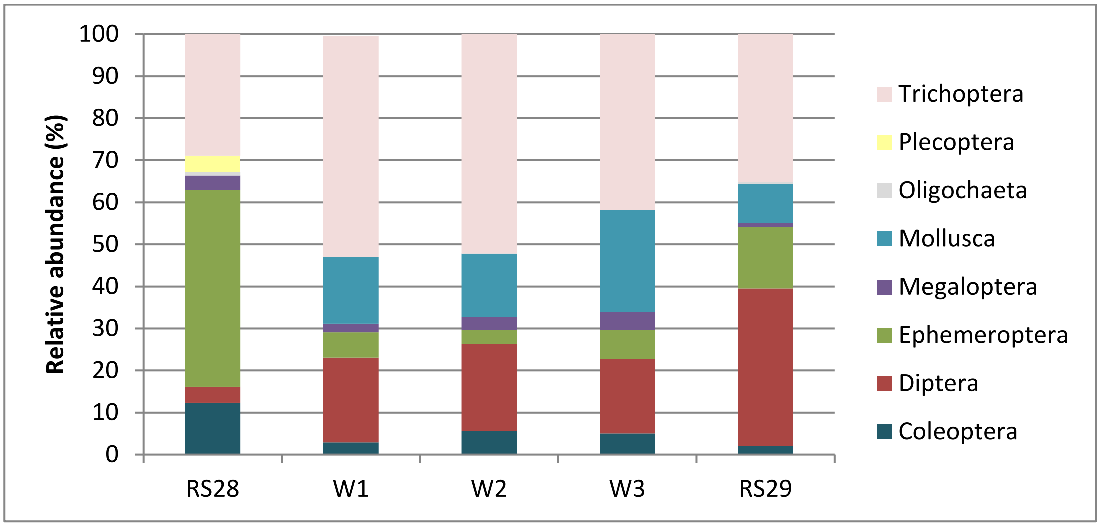

Figure 3-3: Macroinvertebrate community composition by relative abundance at sites on the Wainuiomata River (data from GWRC RSoE sites, 2014 and MWH, 2015).

3.1.6.1 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 Wainiuomata 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, 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.

3.1.6.2 Comparison between the application area and upstream reaches

Macroinvertebrate community composition, invertebrate metrics and habitat quality scores from within the application area are similar to those recorded at the downstream RSoE site, but both the application area and downstream RSoE site are markedly different from the upstream reference site.

The observed differences in macroinvertebrate community composition between the upstream reference sites and the application area / lower-river are largely explained by the reduction in indigenous forest cover and increase in production pasture in the contributing catchment. The transition in a downstream direction from the forested upper catchment to the developed area of the Wainuiomata Valley includes a progressive loss of integrity of riparian edge vegetation, a doubling of dissolved nitrogen concentrations, an increase in algae productivity, and nearly a halving of visual clarity. 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.

It is not possible to draw conclusions about the effects of flood protection activities on macroinvertebrate communities based on these monitoring results because the river reach managed by flood protection lies within the urban area where macroinvertebrate habitat quality is already reduced by land use activities. 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 Wainuiomata River catchment over the period 1960 to 2015 (42 records). Only four of NZFFD sites are located within the Wainuiomata River application area and 38 sites are located outside of the application area. The number of survey sites within and outside of the application area is listed in Table 3-12.

Table 3-12: 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
Wainuiomata River	4	13	1986 - 2007
George Creek	0	1	1986
Graces Creek	0	1	1986
Wainuiomata-iti Stream	0	1	1986
Catchpool Stream	0	22	1986 - 2002

Twelve species of fish have been recorded within the Wainuiomata River system, including eleven native fish and the introduced brown trout (Table 3-13). In addition, freshwater crayfish (koura) are common throughout the catchment. The distributions of key fish species are shown in Figures 3-4 to 3-7. One species recorded in the Wainuiomata River system, the lamprey, is considered to be threatened (Nationally Vulnerable) while seven fish species are considered to be 'at risk' due to declining numbers nationally (Goodman, *et al*., 2014).

Five fish species have been recorded within the Wainuiomata River application area. These are longfin eel (at 100% of survey sites), brown trout (75%), shortfin eel (50%), common bully (25%) and redfin bully (25%). 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, although redfin bully has a higher predicted occurrence than has been recorded to date. It is noted that only 4 fish records are available for the Wainuiomata River application area, and that those records are dated 1986 and 1988. Additional fish surveys are required to provide a comprehensive characterision of the fish population within the Wainiomata River application area (as proposed in Section 8).

The available information indicates that the core fish community of the Wainuiomata River application area consists of lonfin eel, shortfin eel, common bully, redfin bully and brown trout. Other species such as koaro 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, 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 D and include the following:

- Peak periods of upstream migration of juvenile galaxiid species (whitebait) 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.

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 most trout in the Wainuiomata River system may simply move upstream from adult riverine habitat to spawning areas during May and June.

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 4.8km length of the 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 C and include:

- Inanga spawning habit is located in tidal estuary edge vegetation and occurs during March, April and May. Inanga have occasionally been recorded in the lower river near the coast. Taylor and Kelly (2001) have identified an extensive area suitable for inanga spawning near the river mouth. However, this area is located some 16km downstream of the application area and is therefore not likely to be affected by flood protection activities.
- Other galaxiid species including dwarf galaxiids, koaro, banded kokopu, and giant kokopu, spawn in vegetation or cobbles at the riparian margin between April and August (dwarf galaxiids from September to November). Spawning habitat is generally thought to occur near typical adult habitats (McDowell, 1990; Smith, 2015), mostly outside of the application area.
- 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), i.e., within the application area.
- Brown trout move into headwater tributaries 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 habitat in the Wainuiomata occurs throughout the mainstem of the river, except the lower reach near the coast. However the highest density of spawning occurs in the Catchpool stream which contains excellent habitat (Smith S. , 1986). Recommendations for the protection of trout spawning habitat are given in Section 7.6., and have been incorporated into the Code.

Table 3-13: Summary of the NZFFD records for the Wainuiomata River as of June 2015 (n=42) and FENZ predictions of occurrence inside and outside of the application area (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=38)	Predicted within/ out (FENZ)		
Anguilla australis	Shortfin eel	50	8	50/100	yes	Not threatened
Anguilla dieffenbachii	Longfin eel	100	61	100/100	yes	At risk (declining)
Galaxias maculatus	Inanga	0	3	10/100	yes	At risk (declining)
Galaxias brevipinnis	Koaro	0	8	10/10	yes	At risk (declining)
Galaxias divergens	Dwarf galaxias	0	45	10/100	no	At risk (declining)
Galaxias argenteus	Giant kokopu	0	3	10/10	yes	At risk (declining)
Gobiomorphus cotidianus	Common bully	25	21	20/100	yes	Not threatened
Gobiomorphus huttoni	Redfin bully	25	45	100/100	yes	At risk (declining)
Gobiomorphus hubbsi	Bluegill bully	0	5	10/20	yes	At risk (declining)
Gobiomorphus gobioides	Giant bully	0	3	10/10	yes	Not threatened
Geottria australis	Lamprey	0	11	10/10	yes	Threatened (Nationally Vulnerable)
Salmo trutta	Brown trout	75	58	100/100	yes	Introduced & naturalised

3.1.7.1 Comparison between the application area and upstream reaches

The application area of the Wainuiomata River is located downstream of the indigenous forest area of the water supply catchment but within the urban reach adjacent to Wainuiomata township. The application area is similar to the lower river in terms of land-use and habitat quality, and would be expected to support a similar fish community. The only exception is that inanga are predicted to be present in the lower river but absent from the application area. The recorded distribution of fish species is generally consistent with those predictions, although there is insufficient data to draw any conclusions about the influence of flood protection activities on the distribution of fish. Because of the limited data and the confounding effects of land-use and geographical differences, 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.

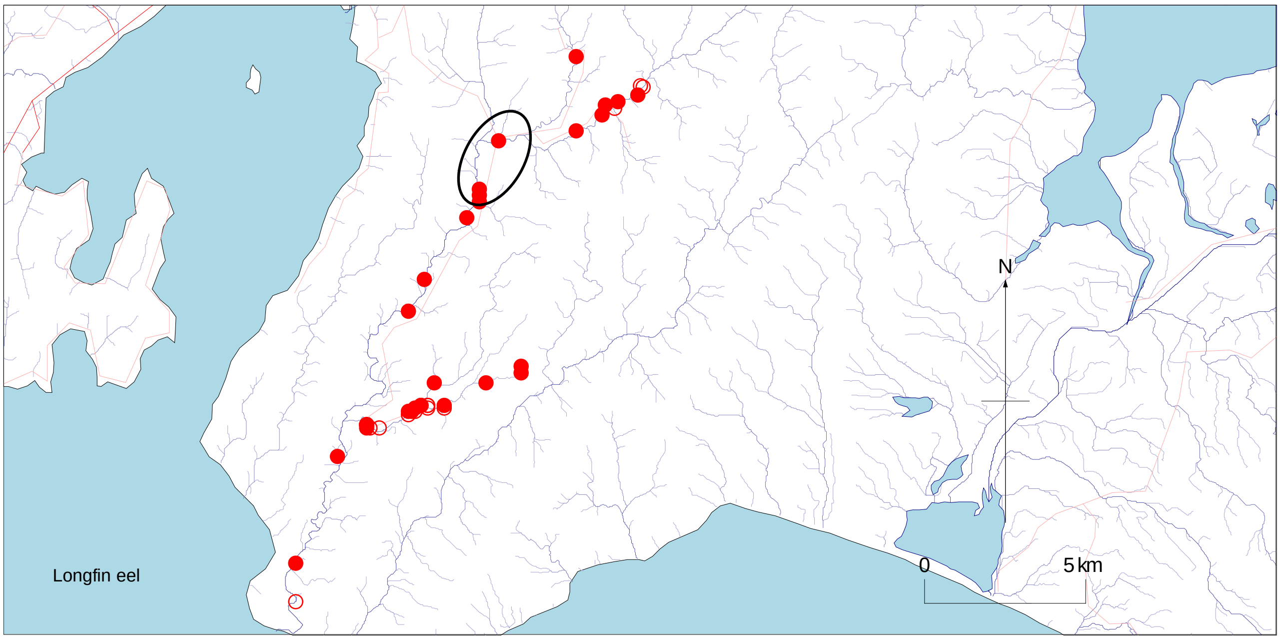

Figure 3-4: Longfin eel records for the Wainuiomata River (presence indicated as red dots, absence by a circle). Data from NZFFD 1980-2013. The Wainuiomata application area is shown as a black oval.

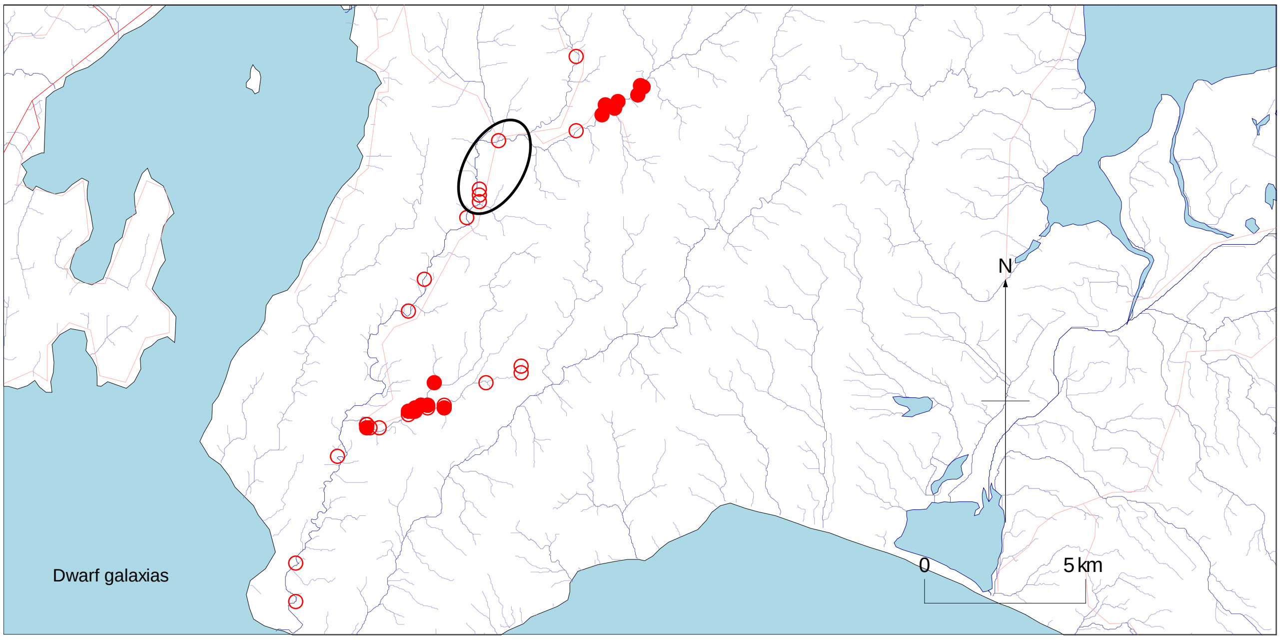

Figure 3-5: Dwarf galaxias records for the Wainuiomata River (presence indicated as red dots, absence by a circle). Data from NZFFD 1980-2013. The Wainuiomata application area is shown as a black oval.

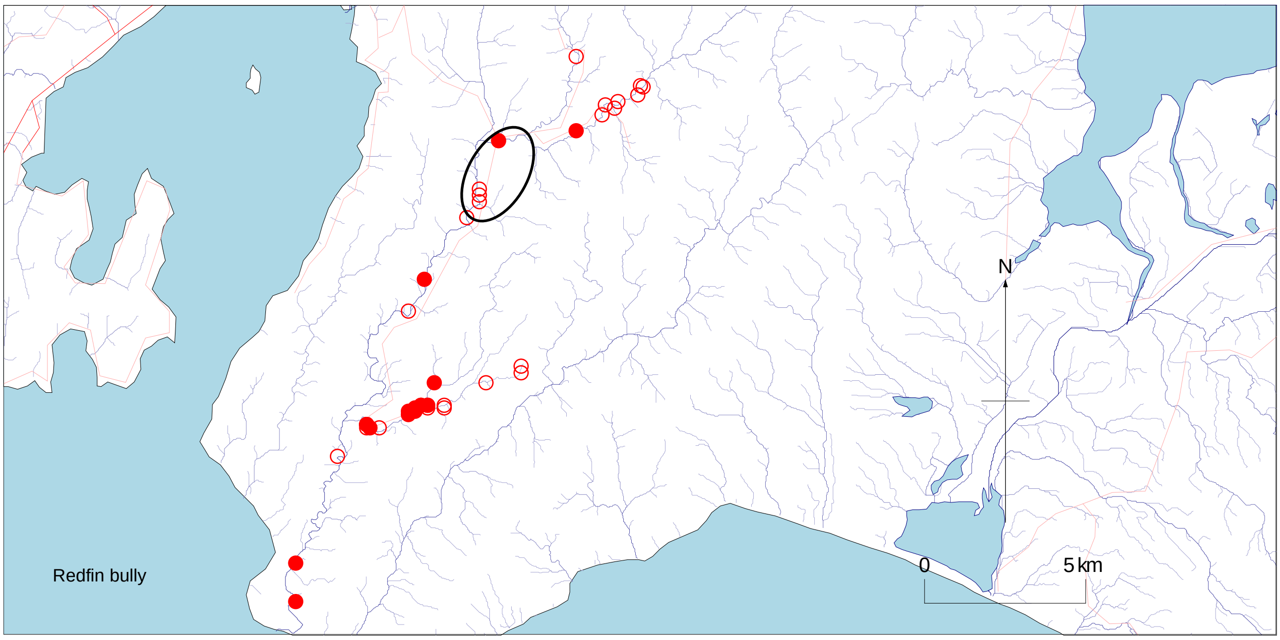

Figure 3-6: Redfin bully records for the Wainuiomata River (presence indicated as red dots, absence by a circle). Data from NZFFD 1980-2013. The Wainuiomata application area is shown as a black oval.

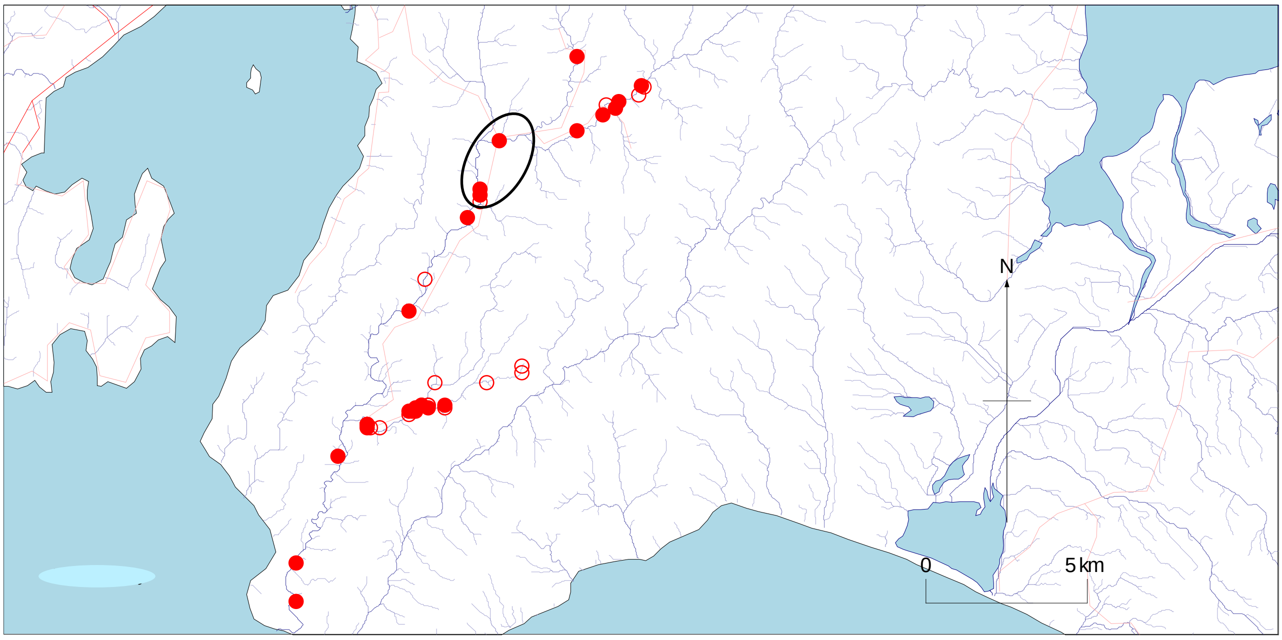

Figure 3-7: Brown trout records for the Wainuiomata River, (presence indicated as red dots, absence by a circle). Data from NZFFD 1980-2013. The Wainuiomata application area is shown as a black oval.

3.1.8 Recreational fisheries

3.1.8.1 Trout

Brown trout were first liberated in the Wainuiomata River in 1876 and continued to be released until the early 1970's. The River is considered to provide a "good" trout fishing experience (Richardson *et al* 1984, Smith 1986). The quality of that experience may have been further enhanced in 2001 by the closure of the Wainuiomata wastewater treatment plant (wastewater is now conveyed to the Seaview for treatment and is then discharges to Cook Strait at Pencarrow).

3.1.8.2 Whitebait and other recreational fisheries

The potential for a whitebait fishery in the lower reaches of the Wainuiomata River is limited by the tendency for the river mouth to be closed by a gravel bar following southerly storms, which could at times prevent juvenile galaxiids and other fish species from migrating from the sea into the river.

3.1.9 Bird values of the Wainuiomata River

3.1.9.1 Introduction

This section summarises current knowledge of the bird values of the Wainuiomata River, with a particular emphasis on the Wainuiomata River mouth, which has been scheduled as a significant bird habitat in Wellington region's Proposed Natural Resources Plan (GWRC 2015; McArthur et al, 2015). Current knowledge is based on regular visits made to the Wainuiomata River mouth between 2011 and 2014 and the results of a four-year investigation into the nesting success of banded dotterels (*Charadrius bicinctus*) at the river mouth (McArthur, 2015) . A brief analysis of the bird habitat values of the river upstream of the river mouth is also provided, based on the local knowledge of the lower reaches of the Wainuiomata River and an examination of available aerial photographs.

3.1.9.2 Results

McArthur (2015) notes that 42 species of birds have been recorded at the mouth of the Wainuiomata River, including 28 native species and 14 introduced species. Of the native species, 12 are ranked as 'At Risk' or Threatened under the New Zealand Threat Classification System (New Zealand eBird database, accessed 13/08/2015; Robertson et al, 2013). Appendix E provides a list of these 42 species and a summary of whether they are 'resident' (encountered during >50% of visits to the site), 'regular visitors (encountered during 10-50% of visits) or 'irregular visitors (encountered during <10% of visits).

Those twelve species included in Appendix E 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. That said however, the majority of these species are restricted to the small area of open sand and gravel habitat present at the river mouth and are very unlikely to venture further upstream where sufficient areas of similar habitat are lacking.

McArthur (2015) found that, based on an examination of aerial imagery of the Wainuiomata River between Wainuiomata township and the river mouth, with the exception of the river mouth, no suitable shorebird habitat exists along this reach of river due to the narrow channel width and very small areas of open gravel beaches. The riparian habitat on either side of the Wainuiomata River appears to be extremely similar to that found along rural and semi-rural reaches of the Waikanae and Hutt Rivers. It would therefore be reasonable to assume that the Wainuiomata River supports a very similar bird community to that found along these sections of the Waikanae and Hutt Rivers. Lists of the bird species detected along these two rivers during annual surveys carried out between 2012 and 2015 can be found in Appendices 2 and 4 of McArthur *et al* (2015). With the exception of those shorebird species recorded at the estuaries of these two rivers, 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). McArthur (2015) concluded that the activities described in the Wainuiomata River flood protection consent application are likely to have a negligible impact on the bird species known or likely to be present along reaches of the Wainuiomata River.

3.1.10 Herpetofauna

A search of lizard and frog records in the Department of Conservation BioWeb Herpetofauna database was undertaken within a 1 km wide corridor extending along the Wainuiomata River channel centreline. (The search area extends well beyond the application area which has a typical width of 25 to 30m.)

There are no records of herpetofauna within the Wainuiomata flood corridor on the Department of Conservation BioWeb *Herpetofauna* database, but this may be due to a lack of survey effort rather than absence of herpetofauna. Hence, the herpetofaunal values of this area are not currently known (Trent Bell, pers. com.). Species likely to be present include the Ngahere gecko, barking gecko, copper skink, northern grass skink and ornate skink. Potential habitat for these species includes screes, boulderfields, rank grassland, scrub, shrubland, secondary forest and primary forest. The likelihood of encountering these species is expected to be low within areas that are frequently inundated by flood flows in the river.

Figure 3-8: The flood corridor search area for Wainuiomata catchment (BioWed contains no records of herpetofauna within the search area).

4 Flood Protection Activities

4.1 Purpose

As described in the Resource Consent Applications for Operations and Maintenance Activities in the Wainuiomata River (Tonkin and Taylor, 2015), the main aims of the river operation and maintenance work programme are to:

- maintain a design channel alignment;
- 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 river, 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)

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 Wainuiomata River

Type of Activity	Individual Activities
Construction of "Impermeable" Erosion Protection Structures on & in the river bed	Groynes constructed of gravel, 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 arrestor Permeable groynes
Construction of other works outside the river bed (on berms and stopbanks within the river corridor)	Cycleway/walkway construction and associated new stormwater drainage, culverts, footbridges and access ways 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	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 • Banks and berms
Development of vegetative bank protection	Tree Planting Willow layering, cabling & tethering
Maintenance of vegetative works	Trimming and mulching 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 (including ripping) Mechanical bed re-contouring Mechanical ripping in the wetted channel
Channel maintenance	Removal of vegetation Beach ripping Clearance of flood debris Gravel extraction
Non-structural maintenance works outside the river bed	Mowing stopbanks & berms Drain maintenance Water blasting Trimming and mulching of vegetation Planting & landscaping
Contingency works	Any of the above in response to flood or an emergency situation

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 as well as 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 populations (Harding *et al* 2009) and it is 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 Wainuiomata catchment, although some straightening and confinement has occurred, the river has retained a moderate degree of natural character compared to other rivers in the western region. 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 individual operations and/or maintenance activities listed in Table 4-1 on the water quality and ecology of the Wainuiomata River. It is noted that the part of the river managed by GWRC Flood Protection is a relatively short 4.8 km reach in the urban area. It is also noted that the scale of flood protection activity undertaken in this area is relatively small compared to other rivers in the western region, and that many of the activities listed in Table 4-1 have to date not been applied in the Wainiuomata River.

5.2 Water Quality

The primary effects on water quality associated 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). The results in Table 5-1 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.

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 (Table 5-3). Bulldozer channel shaping in the Waikanae River has generated suspended solids concentrations as high as 690 mg/L.

In the Hutt River, and probably also in the Wainuiomata 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[3]. 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 generally 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.

[3] It is noted that biochemical conditions inside *Phormidium* dominated mats can, in some instances, be conducive to the release of loosely bound phorphorus, in which case phosphorus may become available for uptake by periphyton (Mark Heath, pers. com.)

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
	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 a 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 typically 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.

Records for the Wainuiomata River indicate that GWRC has not constructed rock groynes in this watercourse to date, but this is a method that might be used in the future.

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 Otaki 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 its lee (Cameron, 2015a). 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 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, 2015a).

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 Wainuiomata River are likely to range from neutral to positive.

McArthur (2015) noted that no suitable shorebird habitat exists within the Wainuiomata River application area due to the narrow channel width and very small areas of open gravel beach. The author concluded that the bird species likely to be present within the application area are all relatively common and widespread in the surrounding landscape, and that flood protection activities in the active channel or riparian area are likely to have a negligible impact on the bird species known or likely to be present along the reach of the Wainuiomata River.

Figure 5-1: Rock groynes, Hutt River (left) and a large rock groyne near Otaki River mouth (right)

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 (Figure 5-2). Hydraulic excavators are used to batter 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 battered 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.

A 15 meter long reach of rock rip-rap lining at Poole Crescent is the sum total in the Wainuiomata River to date, which a very low level of use, and an order of magnitude less than used on other rivers in the western region (Table 5-5).

Table 5-5: Summary of rock rip-rap lineal lengths

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

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. 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.

Figure 5-2: Rock rip-rap linings, Hutt River

McArthur (2015) noted that no suitable shorebird habitat exists within the Wainuiomata River application area due to the narrow channel width and very small areas of open gravel beach. The author concluded that the bird species likely to be present within the application area are all relatively common and widespread in the surrounding landscape, and that flood protection activities in the active channel or riparian area are likely to have a negligible impact on the bird species known or likely to be present along the reach of the Wainuiomata River.

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 arrestor, timber groyne

Description of activity

Debris fences are iron and cable fences that extend from the bank into the river channel (Figure 5-3). They are used to create or re-establish a willow buffer zone along the edge of the river channel, and so maintain channel alignment. They are inter planted with willows and afford protection to these 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

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 Wainuiomata River 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 5-3: 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 Section 5.2. However the diversion (and subsequent removal of the bund) would typically be completed quickly, 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 arrestors causes a temporary release of sediment and other material into the stream, but such a discharge is of short duration and is unlikely to have any lasting adverse effect on 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 Wainuiomata River.

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.

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 approximately 59% of the total river bank length within the Wainuiomata River flood protection area has vegetative bank protection. GWRC has advised that it does not plan to significantly extend the total area of willow plantings in the Wainuiomata River corridor in the future, and that it 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 managed flood protection areas

River	Total bank length (left + right bank)	Total vegetative planting lineal length	Percentage of bank length with vegetative protection
Wainuiomata	9.6km	5.6km	59%
Hutt	56km	32km	57%
Waikanae	14km	7.4km	53%
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 approximately 1.5 m long and 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 5-4).

Figure 5-4: Willow pole planting (note native plantings in foreground)

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 river 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 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 an environmental monitoring plan.

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.

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 (Figure 5-5). 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.

Figure 5-5: Vegetation and silt clearing from a drain beside the Hutt River

Potential effects

Clearance of aquatic macrophytes and silt from low gradient drains is likely to result in significant short term disturbance. Hand clearance is the least disruptive method but may not be viable in many watercourses. Mechanical excavation can result in the immediate loss of a high proportion of the available plant cover. Potential adverse effects of vegetation removal listed by Greer (2014), which are relevant to the Wainuiomata River application area include the following:

- *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 an extended period of time 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 the Wainuiomata application area are listed in Section 7.5.

5.10.3 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 the gravel armouring layer by dragging a tine through it. This facilitates the mobilisation of the gravel during floods (Figure 5-6). Both activities involve excavation or disturbance of bed material but do not typically result in a discharge of sediment to the flowing channel.

Figure 5-6: Beach ripping, Hutt River.

Potential effects

These activities are unlikely to have any immediate downstream effects on water quality or aquatic habitat. Beach ripping 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, 2012). However, the Wainuiomata River application area does not contain suitable shorebird habitat due to its narrow channel width and very small areas of open gravel beach.

5.10.4 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; any beach or bed contouring completed at a location where debris removal occurs is accounted for as beach or bed recontouring.

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 & Richardson (1995) suggest 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.

5.10.5 Gravel extraction

Description of activity

Gravel bed material is extracted from the river in order to maintain bed levels within a design envelope of maximum and minimum 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).

Gravel bed material is to be extracted from dry beaches on Wainuiomata River (above the low flow channel). A regular annual gravel extraction programme is not proposed, rather extraction would typically be undertaken from time to time in response to a major flood event. It is estimated an average extraction rate of 1,500 m^3/per year (over the term of the consent) will meet this requirement. Most of this work is expected to occur downstream of Black Creek (especially around Wood Street and Burden Avenue).

Gravel is pushed up into stock piles by an excavator and then loaded onto trucks for removal. Trucks may need to cross the river in some instances but in general the disturbance of riverbed materials within the active channel is relatively minor.

Potential effects

(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 in this case, due to the limited extent of gravel beaches and narrow river channel in the Wainuiomata River, the river reach managed by GWRC Flood Protection does not support breeding populations of river nesting bird species (McArthur, 2015).

(ii) Disturbance of Herpetofauna

There are no records of herpetofauna within the Wainuiomata flood corridor on the Department of Conservation BioWeb *Herpetofauna* database, although this may be due to a lack of survey effort rather than absence of herpetofauna. Species potentially present within the river corridor include the Ngahere gecko, barking gecko, copper skink, northern grass skink and ornate skink. Potential habitat for these species includes screes, boulderfields, rank grassland, scrub, shrubland, secondary forest and primary forest. However, the likelihood of encountering these species is expected to be low within areas that are frequently inundated by flood flows in the river. Accordingly the potential impact on lizard populations within the application area is assessed as negligible and no specific mitigation measures are considered to be necessary.

(iii) Fine sediment mobilisation and deposition

Gravel extraction from the dry is likely to have minimal effects on water quality of the Wainuiomata River, especially given the small volumes of material to be taken. In those cases where trucks are required to cross the river there is potential for minor discharge of suspended sediment (refer Table 5-2) and disturbance of bed material. The latter 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 Wainuiomata catchment which has hard-sedimentary geology, and where the fine sediment content of gravels is low. Nevertheless, Perrie (2013) reported a reduction in substrate size on dry beaches of the Hutt River, where gravel had been previously stockpiled and then removed.

5.11 Channel shaping and realignment

5.11.1 Beach re-contouring

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

Beach recontouring may have implications for river birds and, when done in conjunction with clearing of vegetation from beaches, may improve the quality and/or quantum of river bird roosting and breeding habitat. However, as noted previously, due to the limited extent of gravel beaches and narrow river channel in the Wainuiomata River, the river reach managed by GWRC Flood Protection is thought unlikely to support breeding populations of river nesting bird species.

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. In general, 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 channel bend is done by cutting a new channel 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 profile.

To date bed re-contouring in the Wainuiomata River has been undertaken as a relatively short term solution to the protect bank edges from further erosion. At present three areas in particular require attention:

- The right hand-bend adjacent to Richard Prouse Park
- The right hand-bend adjacent to Wood Street
- The left hand bend adjacent to Leonard Wood Park

The quantity of bed re-contouring undertaken in any year is very dependent on the occurrence of flood events. An analysis of the length of river bed affected by re-contouring over the duration of the current consents shows a total re-contoured lineal length of 690m from 2003 to 2012. This amounts to an average length of 86 m per year, although the actual length has varied between 0 and 275m (Table 5-7).

Table 5-7: Lineal lengths of river bed affected by recontouring over the 13 years to January 2012

	Wainuiomata	Hutt	Waikanae	Otaki
Total lineal length (m)	690*	7050	2580	9620
Average per year (m)	86	542	184	740
Permitted by existing consent: Total (m) per year	100	800	600	1200

*for the 8 years to January 2012

Potential effects

(i) Fine sediment mobilisation and deposition

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. 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 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.

Boubee *et al* (1997) demonstrated, in laboratory tank studies, that some juvenile migratory native fish, particularly banded kokopu, are sensitive to suspended solids concentrations and avoid turbid waters much over 25 NTU (about 120 mg/L suspended solids). Koaro and inanga were found to be less sensitive than banded kokopu, with avoidance response at 70 and 420 NTU, respectively. Short fin and longfin elvers and redfinned bullies showed no avoidance behaviour, even at the highest turbidity tested of 1100 NTU. Subsequently, experiments in a natural stream determined that the rate of movement of migrant banded kokopu declined as turbidity levels exceeded 25 NTU (Richardson *et al*, 2001). Of the native fish species likely to present in the Wainuiomata River application area, koaro is likely to be the most sensitive and eel the least sensitive.

Death *et al* (2013) found that bed recontouring on Waingawa River 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 (suspended solids up to 770 mg/L) but two weeks after completion (and after a minor flood flow) fine sediment cover in riffle habitat 750m downstream of the works was no higher than upstream of the works (Cameron, 2015).

In summary, bed recontouring works have typically caused a marked increase in water column suspended solids, but this effect is temporary and does not continue much beyond the cessation of works. The works have also caused increased rates of sediment deposition in downstream river habitats, but this effect seldom extends much beyond the first fresh.

(ii) Disturbance of benthic habitats

Habitat mapping studies undertaken in the Waingawa and Hutt rivers during bed recontouring (Perrie, 2009; Cameron, 2015) 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; 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 as part of the works (refer Section 7.4).

(iii) Disturbance of macroinvertebrate communities

Fenwick, *et al* (2003) found that despite the major bed 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.

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 Wainuomata River where a diverse benthic community in the river upstream of the works area would be available to re-colonise disturbed reaches (as already occurs after major floods). It is noted however, that where the area of mechanical disturbance involves multiple riffles the overall productivity of that reach will be reduced, potentially reducing food supplies for fish.

(iv) 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 bed recontouring works over a 220m river length (Cameron, 2015). The results of that study showed that the works caused a major change in habitat characteristics. 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 good quality habitat for them there.

Death et al (2013) found that bed re-contouring on Waingawa River temporarily affected fish numbers, but, provided suitable habitat was available, the fish fauna recovered rapidly, usually after the first fresh. 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".*

Surveys of trout numbers undertaken by Fish & Game divers before and three months after disturbance by gravel extraction in the Hutt River found that trout were relatively abundant at both disturbed and undisturbed reaches, indicating that any adverse effects that had occurred were relatively short-lived (Cameron, 2015).

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 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).

It is our recommendation that where there is a potential for loss of important habitat due to river engineering works, 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 riffle, pool and/or backwater 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).

(v) Disruption of fish spawning and/or migration

As described in Section 3.1.7 the Wainuiomata River application area provides spawning habitat for a number of fish species:

- Galaxiid species including koaro, banded kokopu, shortjaw 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 minor watercourses upstream (or downstream) of the application area. Nevertheless, limited spawning may occur within 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.
- Trout move into headwater tributaries to spawn during May and June. Limited trout spawning habitat may occur in the Wainuiomata River application area.

(vi) General comments

Bed recontouring has the potential to cause significant adverse effects on the river ecology, at least in the short term. Bed disturbance and discharge plumes have the potential to interfere with juvenile fish migration and to disrupt spawning of galaxiids, bullies and possibly brown trout. These effects could, however, be avoided or mitigated by limiting the amount of bed disturbance that can occur during periods of peak upstream migration & spawning, as specified in Section 7.6 (and summarised in Table 5-8).

Table 5-8: Recommended constraints of works in the wetted river channel – Wainuiomata River

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wainuiomata River					No works in trout spawning reaches				No more than 3 day's work per site or 15 days in the application area			

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.

6 Cumulative Effect

There is some potential for the effects of GWRC operations and maintenance activities to be increased by other similar activities undertaken in the catchment by other parties. We note that one landowner downstream of the GWRC managed reach has consent to undertake limited works in the river adjacent to his property, and that a number of other landowners are also seeking the ability to undertake flood protection works in the river adjacent to their own properties. Some of these works could be similar to those undertaken by GWRC and could therefore have some cumulative effect. It is understood, however, that the scale of any such works would be relatively minor and infrequent and that the resulting cumulative effect would be minimal.

There may be a cumulative effect resulting from the extension of permanent works (i.e. rip-rap linings) however the extent of such structures is very low in the Wainuiomata 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 Hutt River at 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. In the case of the Wainuiomata River, where the level of flood protection has historically been very low, the weight of evidence indicates that cumulative effects are likely to be negligible.

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 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 Wainuiomata River within the application area 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, the Wainuomata River, with the exception of the river mouth, does not support a breeding population of riverbed nesting shorebirds, and accordingly no specific recommendations have been made in respect of dry gravel beaches.

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,
- protection of high-value areas of riparian native vegetation which are threatened by erosion.

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 re-colonise.

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

- planting above 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 streams and drains 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 (where appropriate with reinstated artificial structures);
13. Preserve specific important habitats such as riffles, if they exist;
14. Avoid removing course gravel and cobble substrates, if it is present;
15. 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 over the 4.8 km of river length within the 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 trout spawning habitat it is recommended that:

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

8 Monitoring

8.1 Overview

Monitoring the effects of flood protection activities is proposed by GWRC to be undertaken in accordance with the EMP, which is included in Section 3 of the Code. The EMP proposes a programme of baseline monitoring and specific event monitoring. In the Otaki, Waikanae, Hutt and Ruamahanga river systems, where the areas of river managed by Flood Protection are relatively extensive, baseline monitoring will consist of regular measurement of a range of geomorphological and biological variables in each of the reaches defined for assessment of a natural character index (NCI). The Wainiuomata River application area is small by comparison and historically the quantum of flood protection activities undertaken in the Wainuiomata River has been very low. For instance over the last 15 years there has been no gravel extraction, no rock groyne construction, a total of 15 metres length of rock rip-rap has been constructed, and a total of 690 metres of riverbed length has been recontoured. GWRC has been able to rely on vegetative bank protection as the primary method for managing the flood and erosion risks, and that is expected to continue into the future (except possibly in response to a major damaging flood event).

In recognition of the low level of flood protection activity in the Wainuiomata River a relatively low level of baseline monitoring is proposed. However, additional site specific ‘event’ monitoring would be undertaken for any ‘moderate’ or ‘large’ scale works, as described below.

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 Fish Communities

The New Zealand Freshwater Fish Database (NZFFD) contains a significant amount of information about freshwater fish communities in the Wellington Region. However, the fish communities of the Wainuiomata River application are not well characterised.

It is recommended that further investigations be undertaken at three yearly intervals in selected reaches of the Wainuiomata River for the duration of the consent (or until modified by review of the EMP). It is further recommended that these reaches should be include reference and impact sites (to the extent that is possible within the application area).

8.2.3 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 Wainiuiomata 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.

8.3 Event Monitoring

In the first instance, event monitoring will focus on those activities deemed to have the most potential for adverse effects, which is the Wainuiomata River is 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. Baseline monitoring will be undertaken as described in 8.2 above. 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 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 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 perennial streams

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

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 Wainuiomata River application area in order to maintain the river channel within its design alignment, maintain the flood capacity of the river channel, and maintain the integrity and security of existing flood defences which provide for the safety and well-being of the Wainuiomata communities. 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 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 and channel realignment 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 220 m 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. This could have been improved if the channel realignment had been based on creation of a meander pattern (which it was not) and reconstruction of some channel complexity had been incorporated into the works.

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. 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. However the level of flood protection activity likely to occur in the Wainuiomata River is low by comparison with other rivers in the Wellington region, and the potential of cumulative adverse effects is also relatively low. It is proposed 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 for the river over time.

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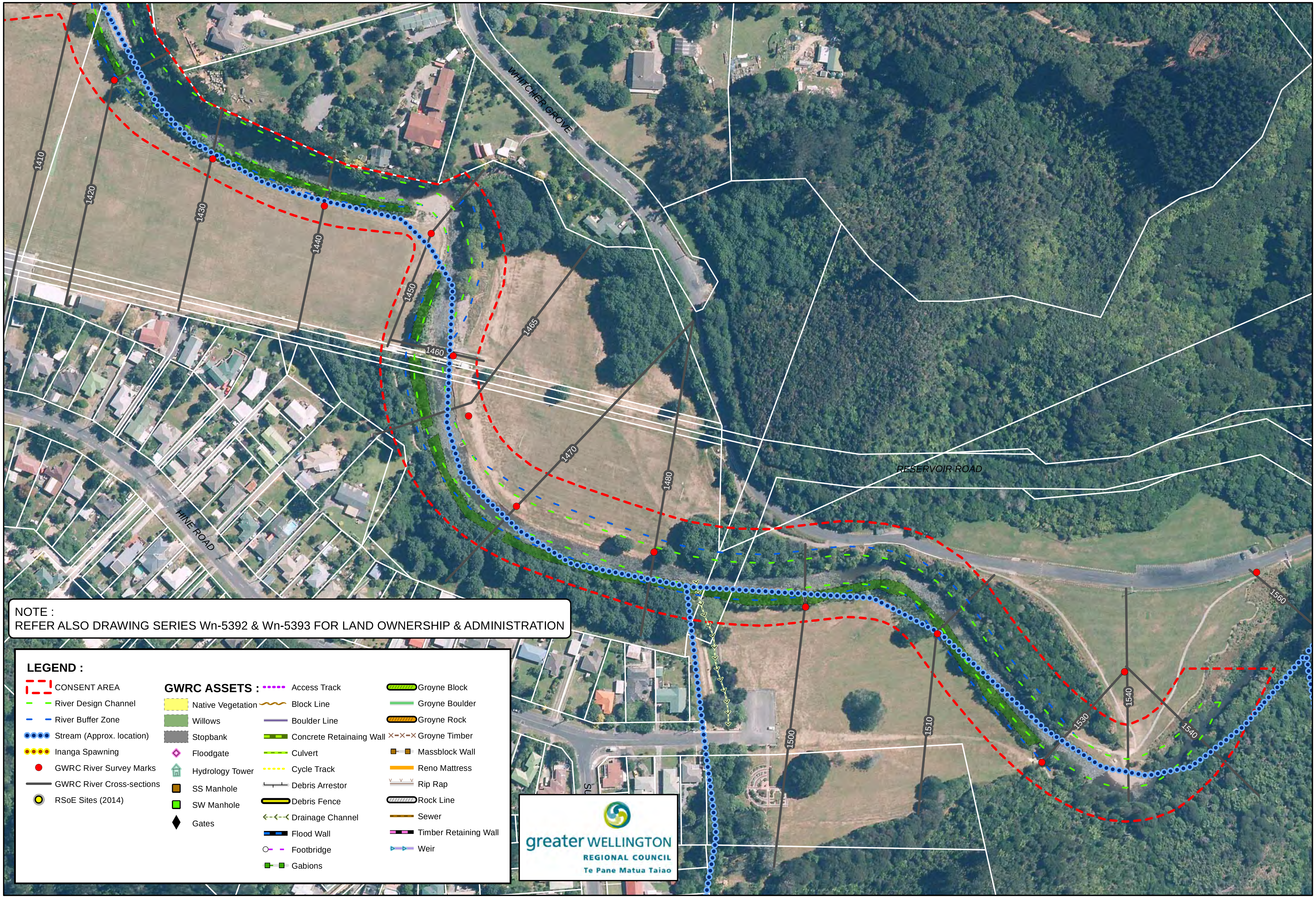
Appendix A Wainuiomata River Map Series



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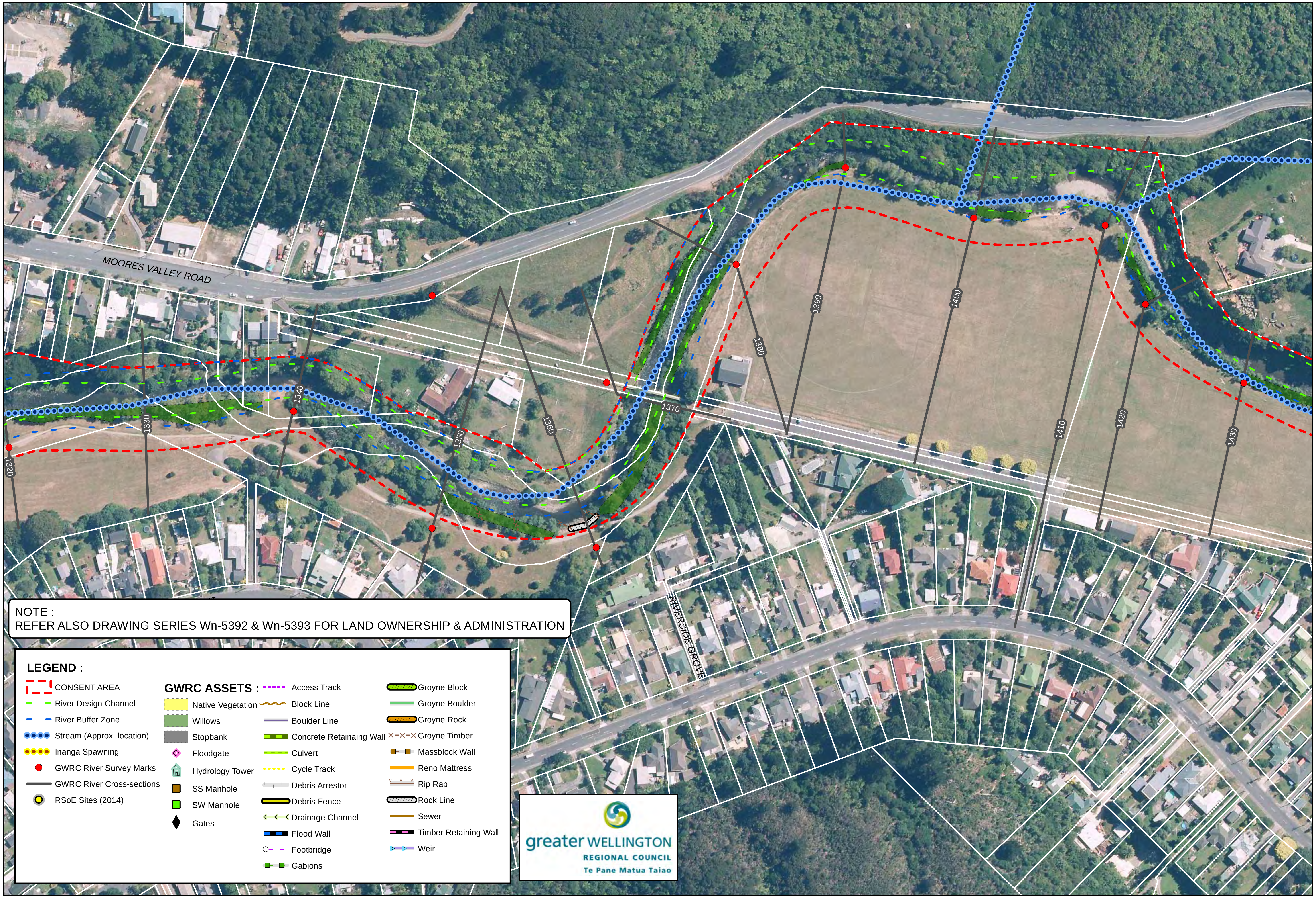
WAINUIOMATA RIVER - CONSENT AREA

Map 1b - GWRC Asset & Ecological Information

Aerial Photography : GW Jan. 2013
Drawn : P.Cook
Date Plotted : 7 July 2014

DWG No. **Wn-5408 / 1**

N



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TOPOGRAPHIC AND CADASTRAL DATA IS COPYRIGHT LINZ

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A3 Scale :1:2,000

WAINUIOMATA RIVER - CONSENT AREA
Map 2b - GWRC Asset & Ecological Information

Aerial Photography : GW Jan. 2013
Drawn : P.Cook
Date Plotted : 7 July 2014

DWG No. **Wn-5408 / 2**

N

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A3 Scale :1:2,000

WAINUIOMATA RIVER - CONSENT AREA
Map 3b - GWRC Asset & Ecological Information

Aerial Photography : GW Jan. 2013
Drawn : P.Cook
Date Plotted : 7 July 2014

DWG No. **Wn-5408 / 3**

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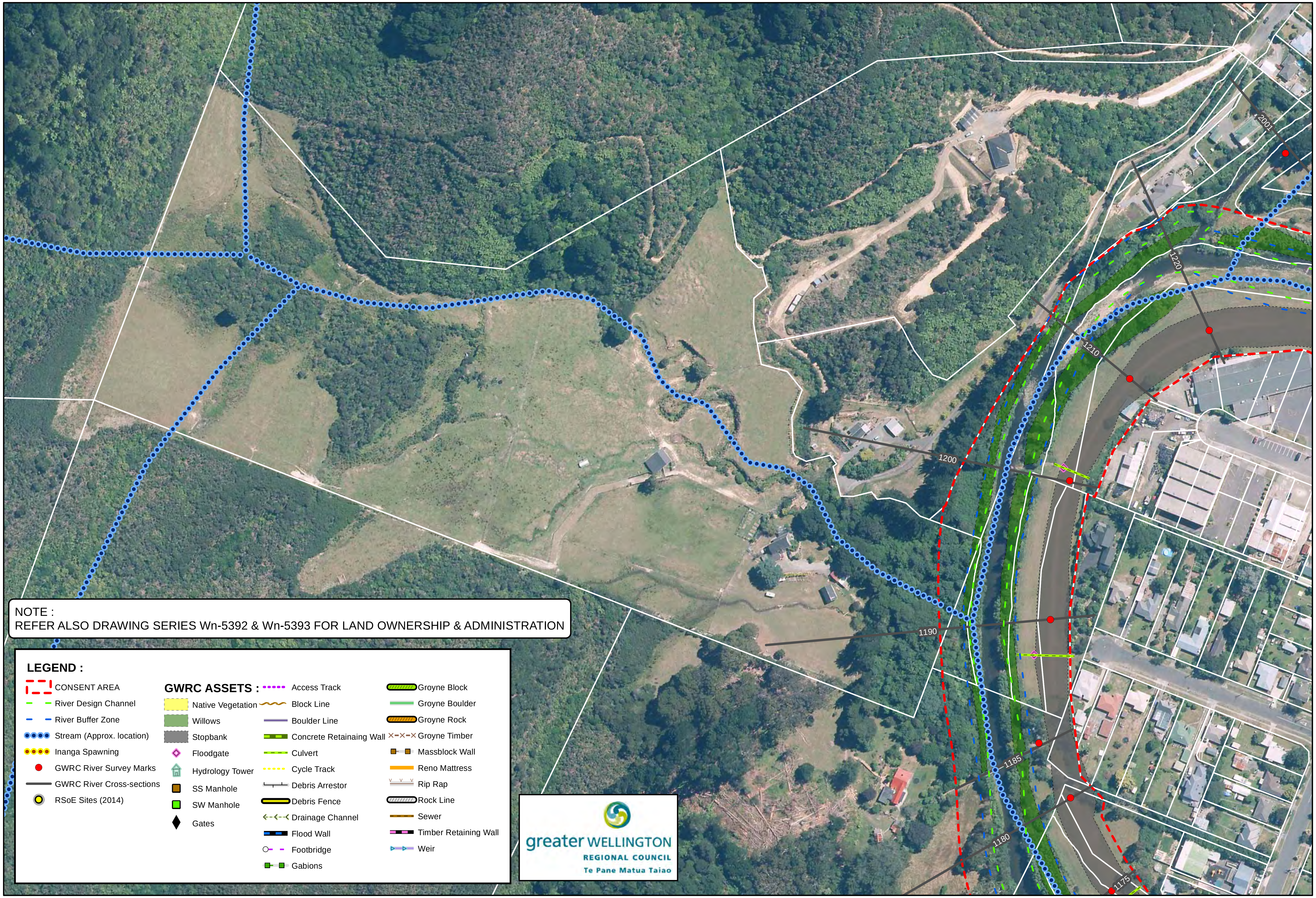

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WAINUIOMATA RIVER - CONSENT AREA
Map 4b - GWRC Asset & Ecological Information

Aerial Photography : GW Jan. 2013
Drawn : P.Cook
Date Plotted : 7 July 2014

DWG No. **Wn-5408 / 4**

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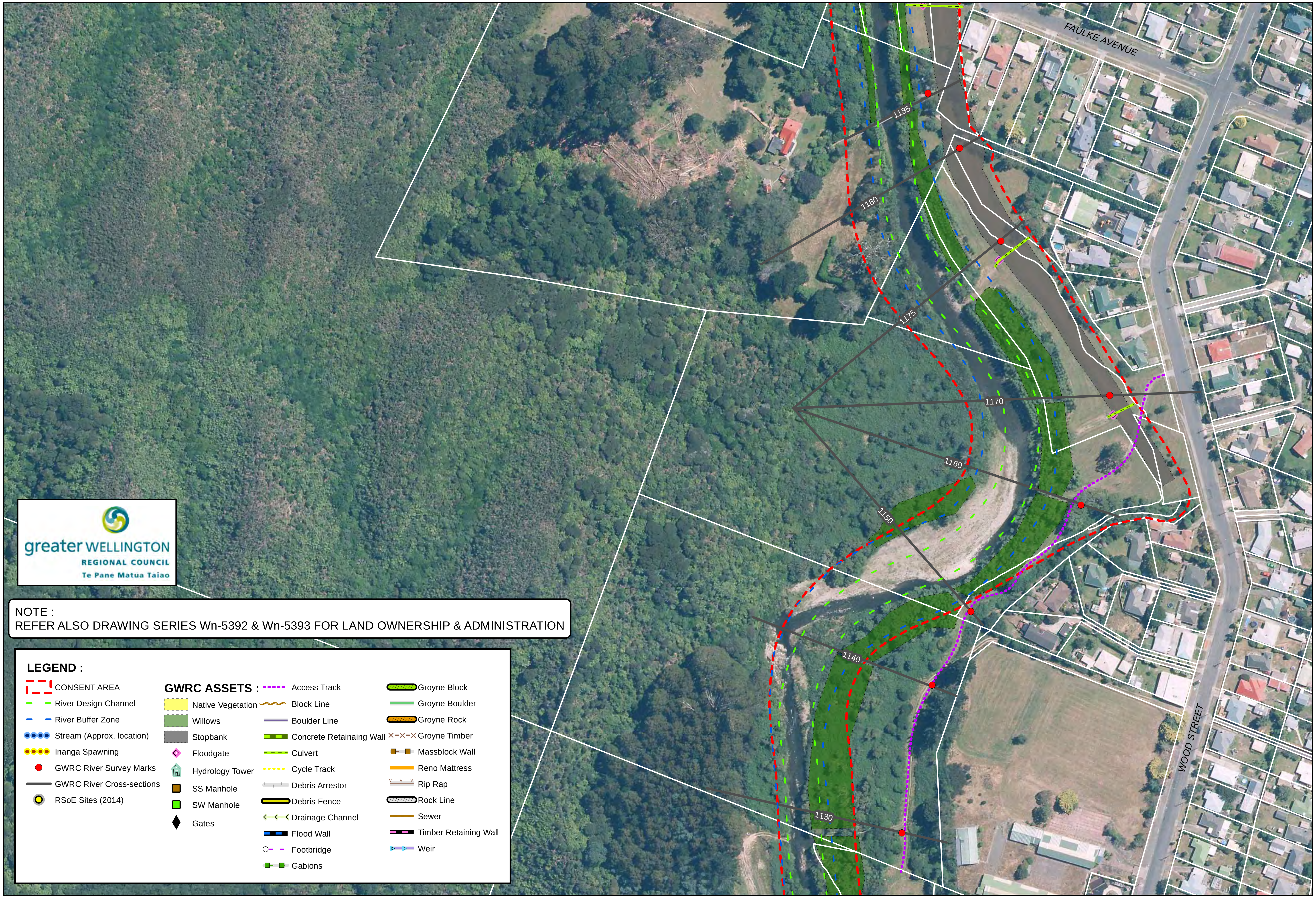

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WAINUIOMATA RIVER - CONSENT AREA

Map 5b - GWRC Asset & Ecological Information

Aerial Photography : GW Jan. 2013
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Date Plotted : 7 July 2014

DWG No. **Wn-5408 / 5**

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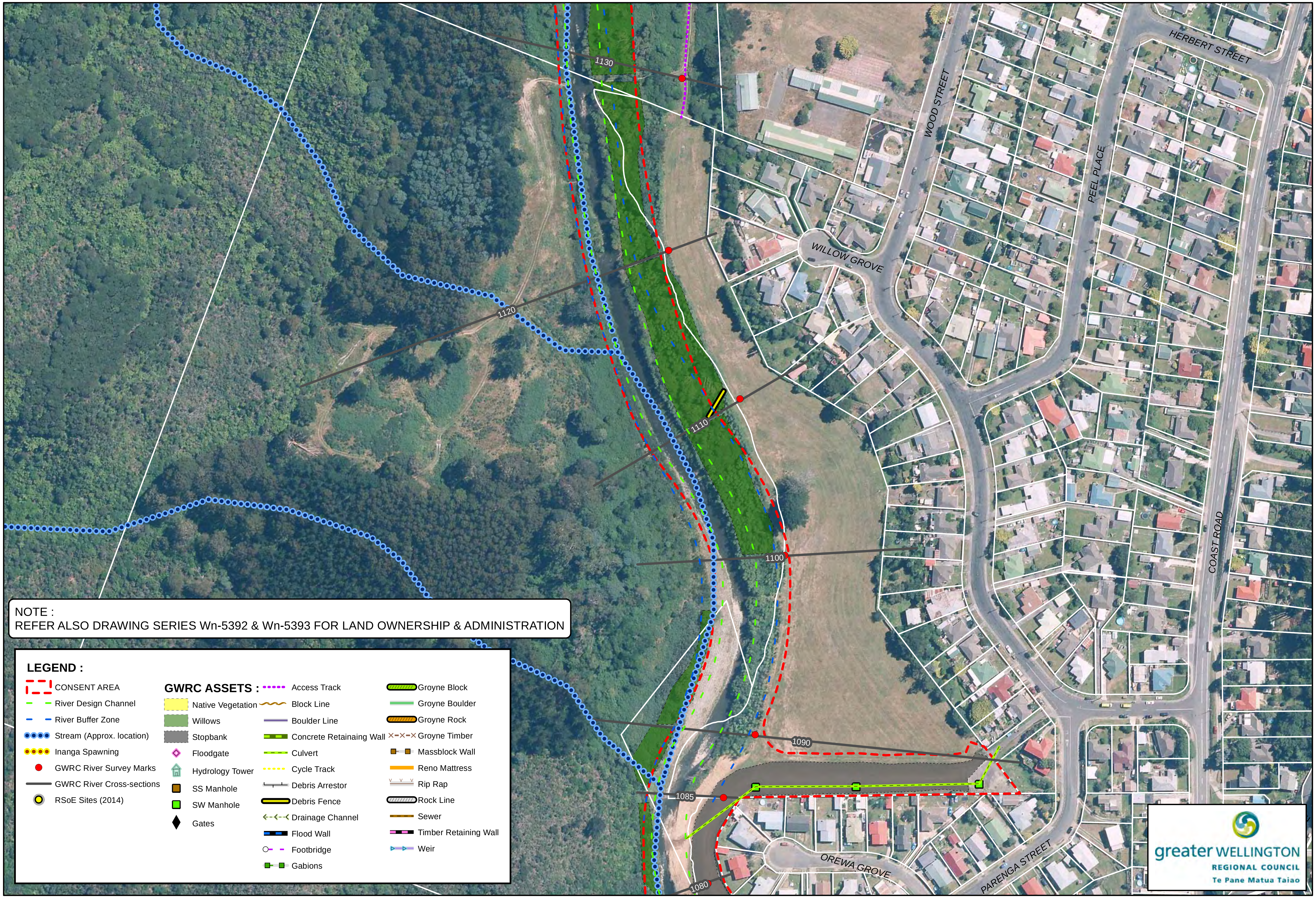

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WAINUIOMATA RIVER - CONSENT AREA

Map 6b - GWRC Asset & Ecological Information

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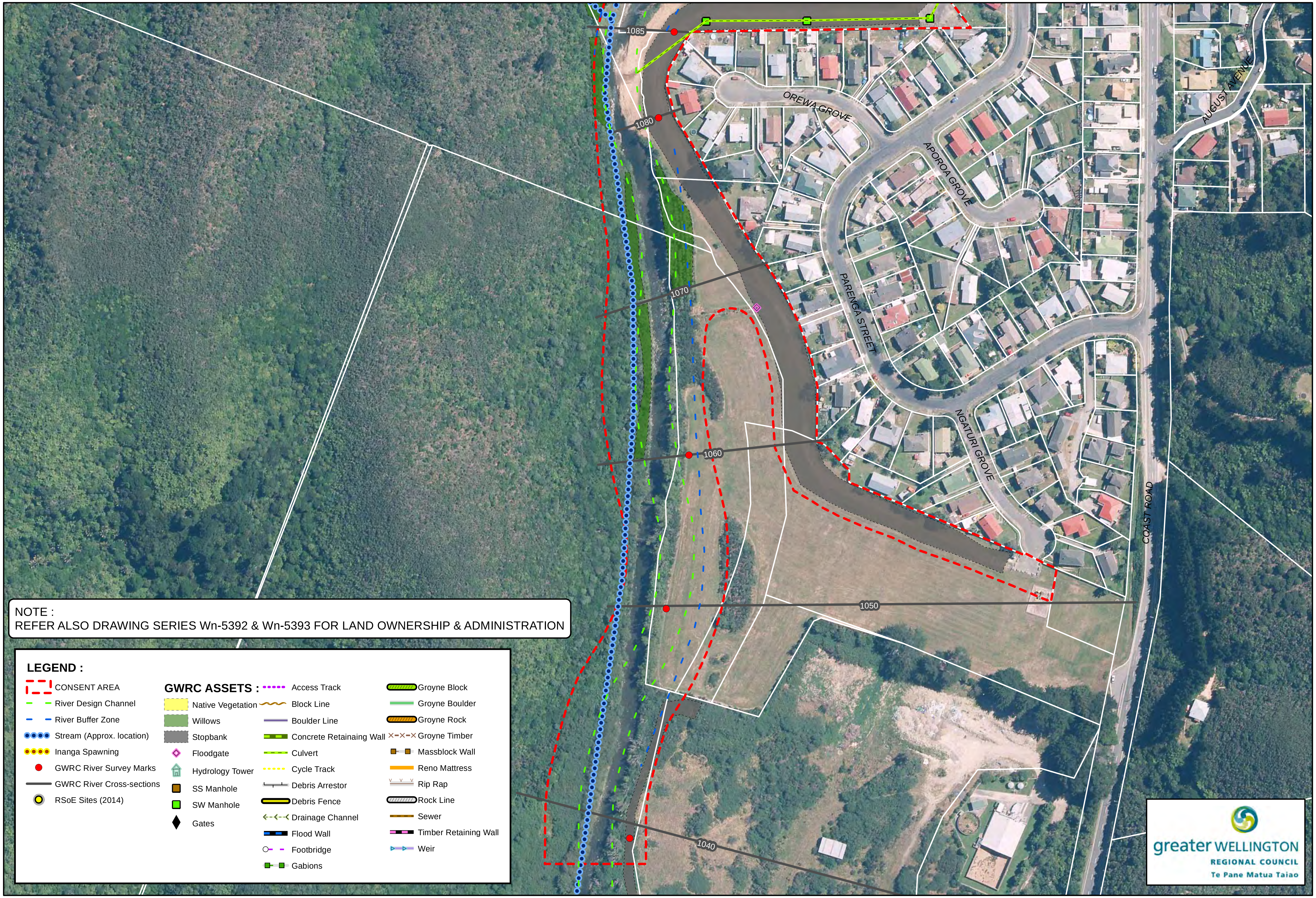

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A3 Scale :1:2,000

WAINUIOMATA RIVER - CONSENT AREA

Map 7b - GWRC Asset & Ecological Information

Aerial Photography : GW Jan. 2013
Drawn : P.Cook
Date Plotted : 7 July 2014

DWG No. **Wn-5408 / 7**

N

Appendix B Boxplots of water quality results by year, from 2004 to 2015 (GWRC RSoE data)

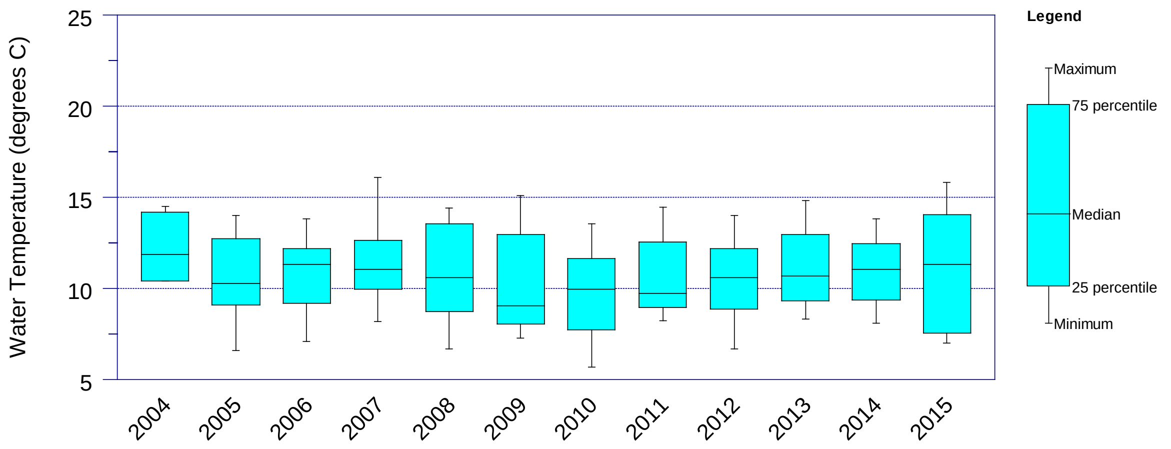

Figure A1: Temperature (ºC) by year in the Wainuiomata River at Manuka Track (Mann-Kendall test shows increasing trend at 4% per year (p=0.015)

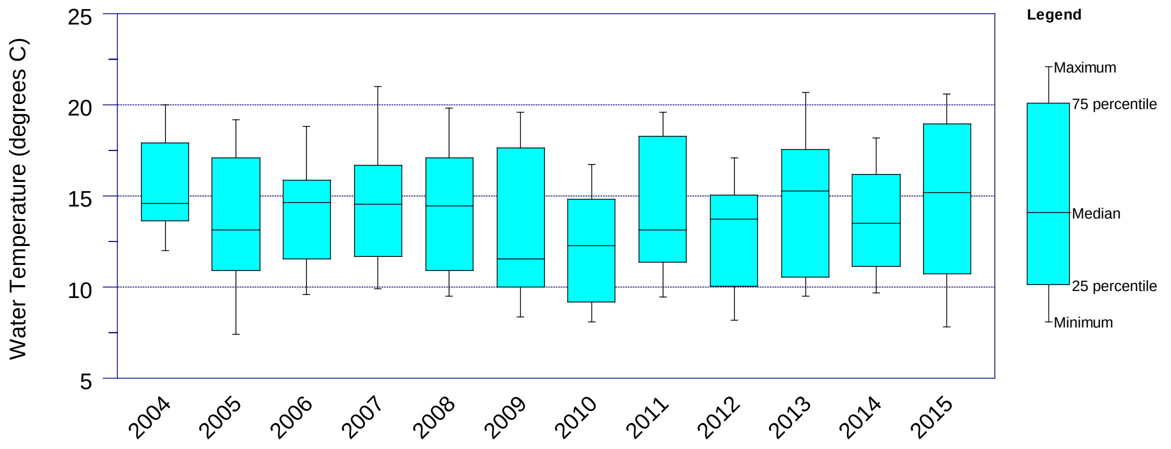

Figure A2: Temperature (ºC) by year in the Wainuiomata River at White Bridge (Mann-Kendall test shows increasing trend at 5% per year (p =0.007)

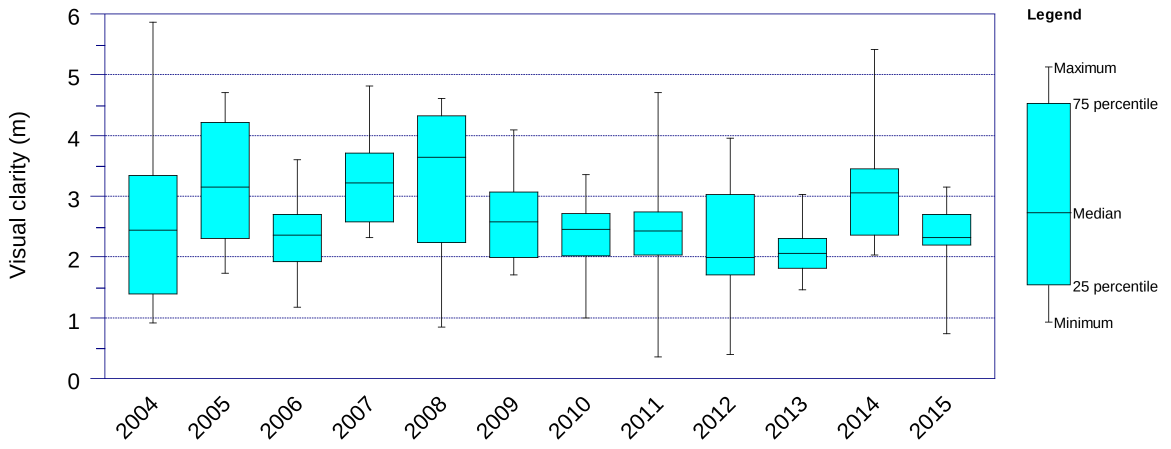

Figure A3: Visual clarity (m) by year in the Wainuiomata River at Manuka Track

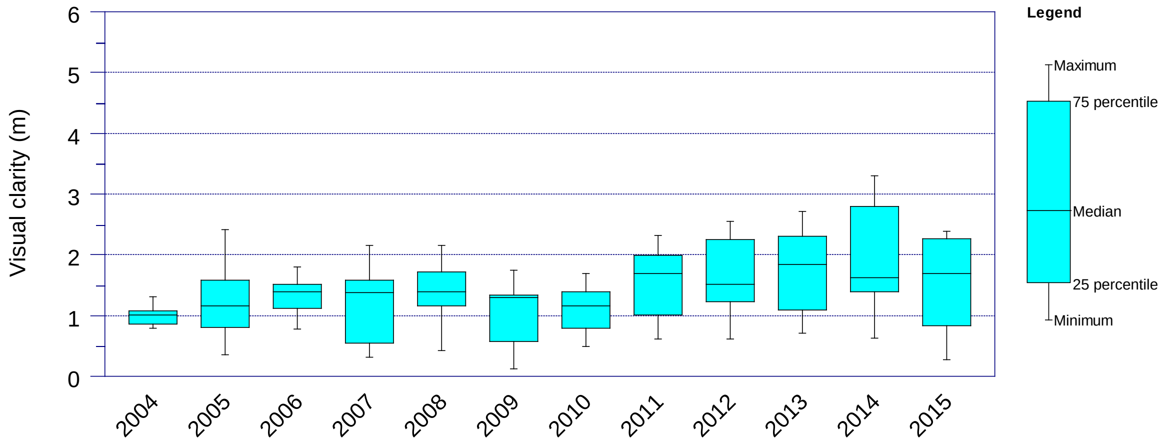

Figure A4: Visual clarity (m) by year in the Wainuiomata River at White Bridge (Mann-Kendall test shows increasing trend at 10.6% per year (p=0.005)

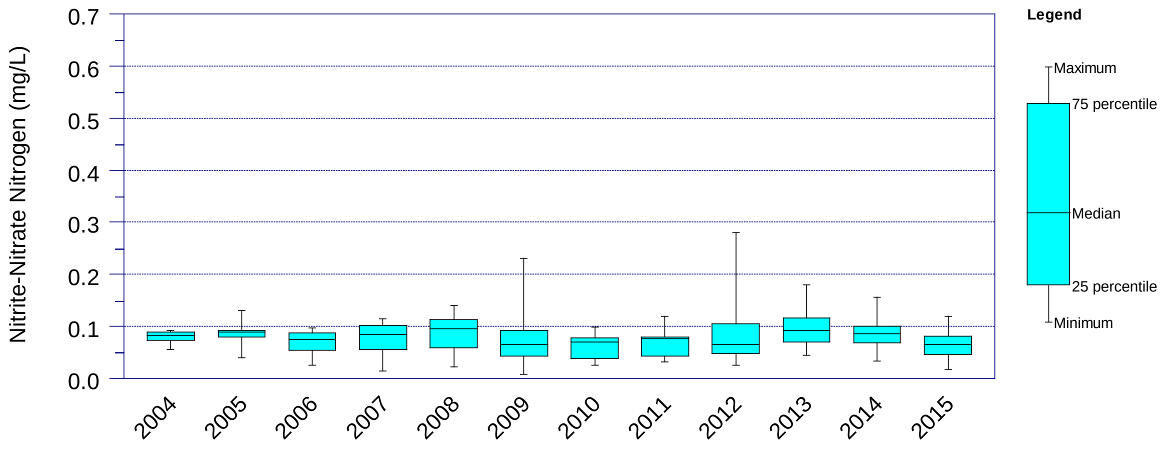

Figure A5: Nitrate + nitrite nitrogen (mg/L) by year in the Wainuiomata River at Manuka Track

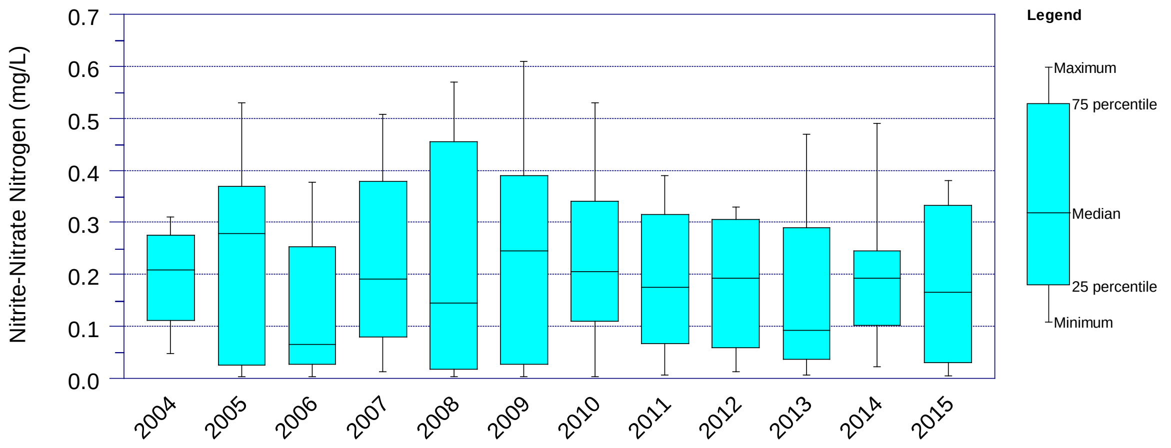

Figure A6: Nitrate + nitrite nitrogen (mg/L) by year in the Wainuiomata River at White Bridge

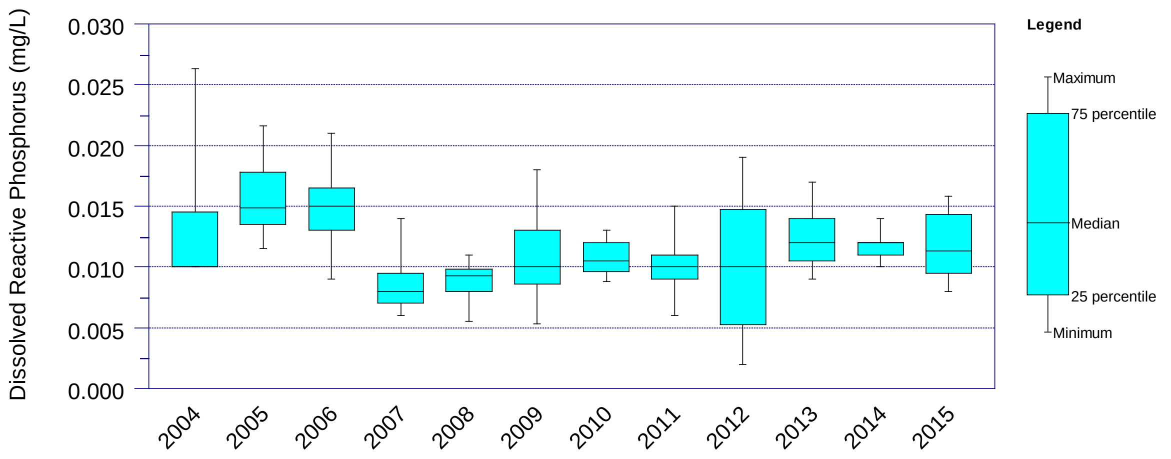

Figure A7: Dissolved reactive phosphorus (mg/L) by year in the Wainuiomata River at Manuka Track (Mann-Kendall test shows increasing trend at 3.6% per year (p=0.016)

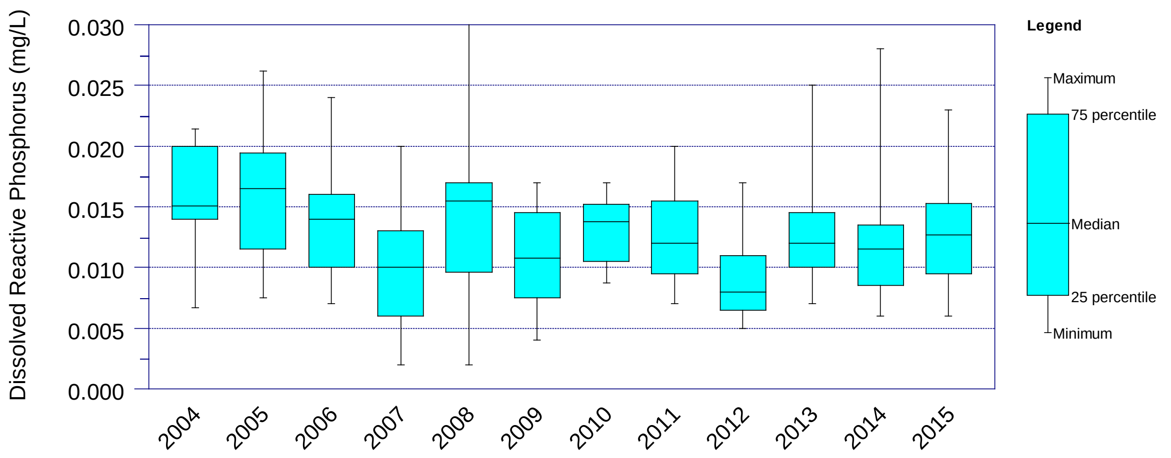

Figure A8: Dissolved reactive phosphorus (mg/L) by year in the Wainuiomata River at White Bridge

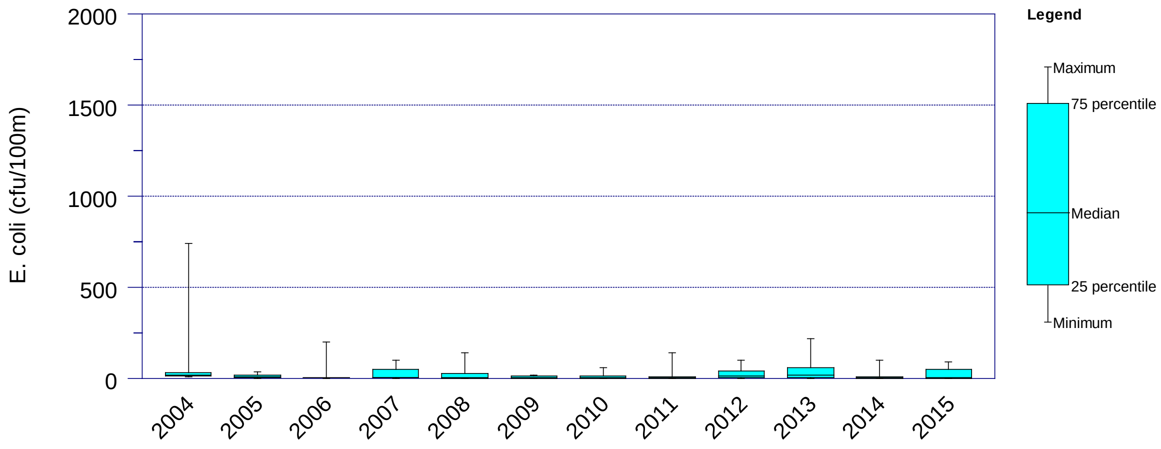

Figure A9: E. coli (cfu/100ml) by year in the Wainuiomata River at Manuka Track

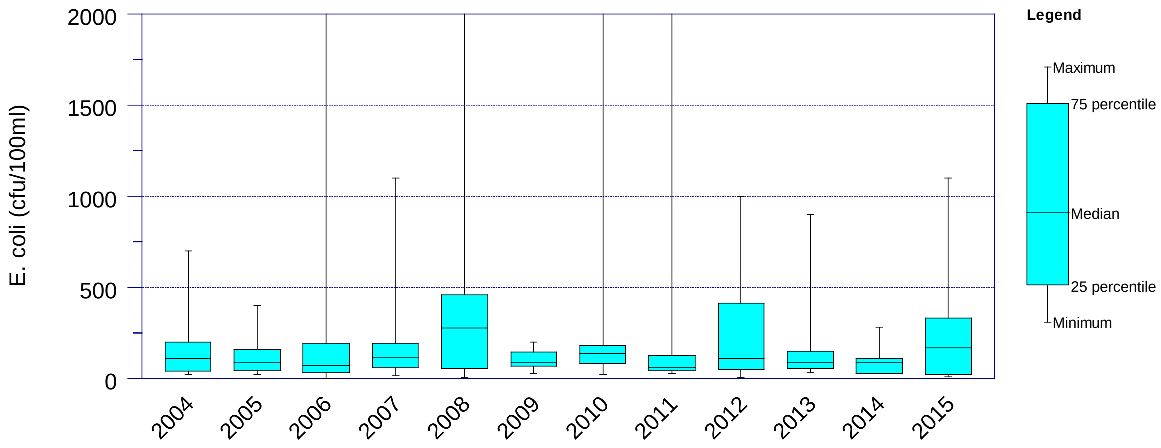

Figure A10: E. coli (cfu/100ml) by year in the Wainuiomata River at White Bridge

Appendix C Macroinvertebrate results for 2014/15

2014 GWRC RSOE and Additional MWH Data	Site No	RS28	W1	W2	W3	RS29
	Site Name	Wainuiomata River at Manuka Track	Wainuiomata at Main Rd Bridge	Wainuiomata at Leonard Wood Park	Wainuiomata below Leonard Wood Park	Wainuiomata River Downstream of White Bridge
	Date sampled	3/03/2014	22/04/2015	22/04/2015	22/04/2015	3/03/2014
Generic Grouping	MCI-level taxa					
Acari	Acari	P				
Coelenterata	Hydra					
Coleoptera	Antiporus					
	Berosus					
	Elmidae	24	13	19	18	3
	Enochrus					
	Hydraenidae	3				1
	Hydrophilidae					
	Liodessus					
	Ptilodactylidae	2				
	Scirtidae					
Collembola	Collembola					
Crustacea	Amphipoda					
	Amphipoda					
	Cladocera					
	Copepoda					
	Isopoda					
	Paracalliope					
	Paraleptamphopus					
	Paratya					
Diptera	Aphrophila	5	5	8	7	1
	Ceratopogonidae					
	Chironomus		7	3	1	
	Corynoneura					
	Ephydridae					
	Eriopterini	1				
	Harrisius					
	Hexatomini					
	Maoridiamesa		40	19	10	11
	Mischoderus					
	Muscidae			2	1	
	Neocurupira					
	Orthocladiinae	2	28	23	24	48
	Paradixa					
	Psychodidae					
	Sciomyzidae					
	Stictocladius	1				
	Stratiomyidae					

	Tabanidae					
	Tanypodinae					
	Tanytarsini		11	14	21	17
	Zelandotipula					
Ephemeroptera	Acanthophlebia	5				
	Ameletopsis	1				
	Austroclima	2	18	9	20	20
	Coloburiscus	18	2	1		3
	Deleatidium	73	7	2	3	7
	Ichthybotus	3	1		1	
	Neozephlebia	2				
	Nesameletus	3				
	Oniscigaster					
	Rallidens					
	Zephlebia	3				
Hemiptera	Anisops					
	Microvelia					
	Sigara					
Hirudinea	Hirudinea					
Lepidoptera	Hygraula					
Megaloptera	Archichauliodes	8	9	11	16	2
Mollusca	Ferrissia					1
	Gyraulus					
	Physa					
	Potamopyrgus		72	51	86	18
	Sphaeriidae					
Nematoda	Nematoda					
Neuroptera	Kempynus					
Odonata	Anisoptera					
	Antipodochlora					
	Austrolestes					
	Xanthocnemis		2			
Oligochaeta	Oligochaeta	2				1
Platyhelminthes	Platyhelminthes					
Plecoptera	Acroperla					
	Austroperla	7				
	Megaleptoperla					
	Spaniocerca					
	Stenoperla	1				
	Zelandobius					
	Zelandoperla	1				
Polychaeta	Polychaeta					
Trichoptera	Aoteapsyche	21	213	139	101	36
	Beraeoptera	1	1	2		
	Costachorema	2	3	2		
	Helicopsyche	3				

	Hudsonema		1			
	Hydrobiosella	2	1			
	Hydrobiosis	7	2	5	5	2
	Hydrochorema	1				
	Neurochorema		3	1	2	P
	Oecetis					
	Oeconesidae					
	Olinga	23	2	2	4	9
	Orthopsyche					
	Oxyethira		1		1	
	Paroxyethira					
	Plectrocnemia					
	Polyplectropus					
	Psilochorema	3	1	1	2	
	Pycnocentria	3	5	10	16	10
	Pycnocentrodes	2	3	15	20	15
	Triplectides					
Metrics	TOTAL	3728	1525	1326	1417	1312
	TAXA Richness	33	28	25	24	19
	MCI	144	109	104	104	109
	EPT Richness	23	23	12	12	9
	QMCI	7.31	4.20	4.30	4.60	4.61
	% EPT Individuals	79.39	47.27	54.94	48.06	49.79
	% EPT taxa	69.70	50.97	46.67	49.17	47.37

Appendix D Peak periods for upstream fish migration and spawning

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

		Summer		Autumn			Winter			Spring			Summer
Species	Life stage	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												
Lamprey	adult												
Torrentfish	juvenile												
Black flounder	juvenile												
brown trout	adult												

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

		Summer		Autumn			Winter			Spring			Summer
Species	Critical habitat	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												
Lamprey	upper reaches												
Torrentfish	bed												
Dwarf galaxias	?												
Upland bully	bed												
Cran's bully	bed												
brown trout	bed												

Appendix E List of bird species recorded at the Wainuiomata River mouth, 2011- 2015

Data is from McArthur (2015). Threat rankings are as per Robertson et al (2013). Species names and taxonomic order are as per Gill et al (2010).

Scientific name	Common name	Threat ranking	Status	Source
Cygnus atratus	black swan	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Tadorna variegata	paradise shelduck	Not Threatened	Resident, breeding confirmed	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Anas gracilis	grey teal	Not Threatened	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
A. platyrhynchos	mallard	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
A. rhynchotis	Australasian shoveler	Not Threatened	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Callipepla californica	California quail	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Porphyrio melanotus	pukeko	Not threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Phalacrocorax carbo	black shag	At Risk, Naturally Uncommon	Regular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
P. varius	pied shag	Nationally Vulnerable	Regular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
P. melanoleucos	little shag	Not Threatened	Regular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Circus approximans	Australasian harrier	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Egretta novaehollandiae	white-faced heron	Not Threatened	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Haematopus unicolor	variable oystercatcher	At Risk, Recovering	Resident, breeding confirmed	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Himantopus himantopus	pied stilt	At Risk, Declining	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Vanellus miles	spur-winged plover	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015

Scientific name	Common name	Threat ranking	Status	Source
Charadrius obscurus	New Zealand dotterel	Nationally Vulnerable	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
C. bicinctus	banded dotterel	Nationally Vulnerable	Resident, breeding confirmed	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Limosa lapponica	bar-tailed godwit	At Risk, Declining	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Arenaria interpres	ruddy turnstone	Migrant	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Catharacta antarctica	brown skua	At Risk, Naturally Uncommon	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Larus novaehollandiae	red-billed gull	Nationally Vulnerable	Irregular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
L. dominicanus	black-backed gull	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Hydroprogne caspia	Caspian tern	Nationally Vulnerable	Regular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Sterna striata	white-fronted tern	At Risk, Declining	Regular visitor	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Todiramphus sanctus	New Zealand kingfisher	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Prosthemadera novaeseelandiae	tui	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Gerygone igata	grey warbler	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Gymnorhina tibicen	Australian magpie	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Alauda arvensis	Skylark	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Hirundo neoxena	welcome swallow	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Zosterops lateralis	silvereye	Not Threatened	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Turdus merula	blackbird	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015

Scientific name	Common name	Threat ranking	Status	Source
T. philomelos	song thrush	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Sturnus vulgaris	starling	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Anthus novaeseelandiae	New Zealand pipit	At Risk, Declining	Resident, breeding confirmed	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Prunella modularis	dunnock	Introduced and Naturalised	Resident, breeding confirmed	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Emberiza citrinella	yellowhammer	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Fringilla coelebs	chaffinch	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Carduelis chloris	greenfinch	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
C. flammea	redpoll	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
C. carduelis	goldfinch	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015
Passer domesticus	house sparrow	Introduced and Naturalised	Resident	New Zealand eBird database (www.ebird.org/content/newzealand/) Accessed: 12/08/2015

Appendix F Important trout spawning waters

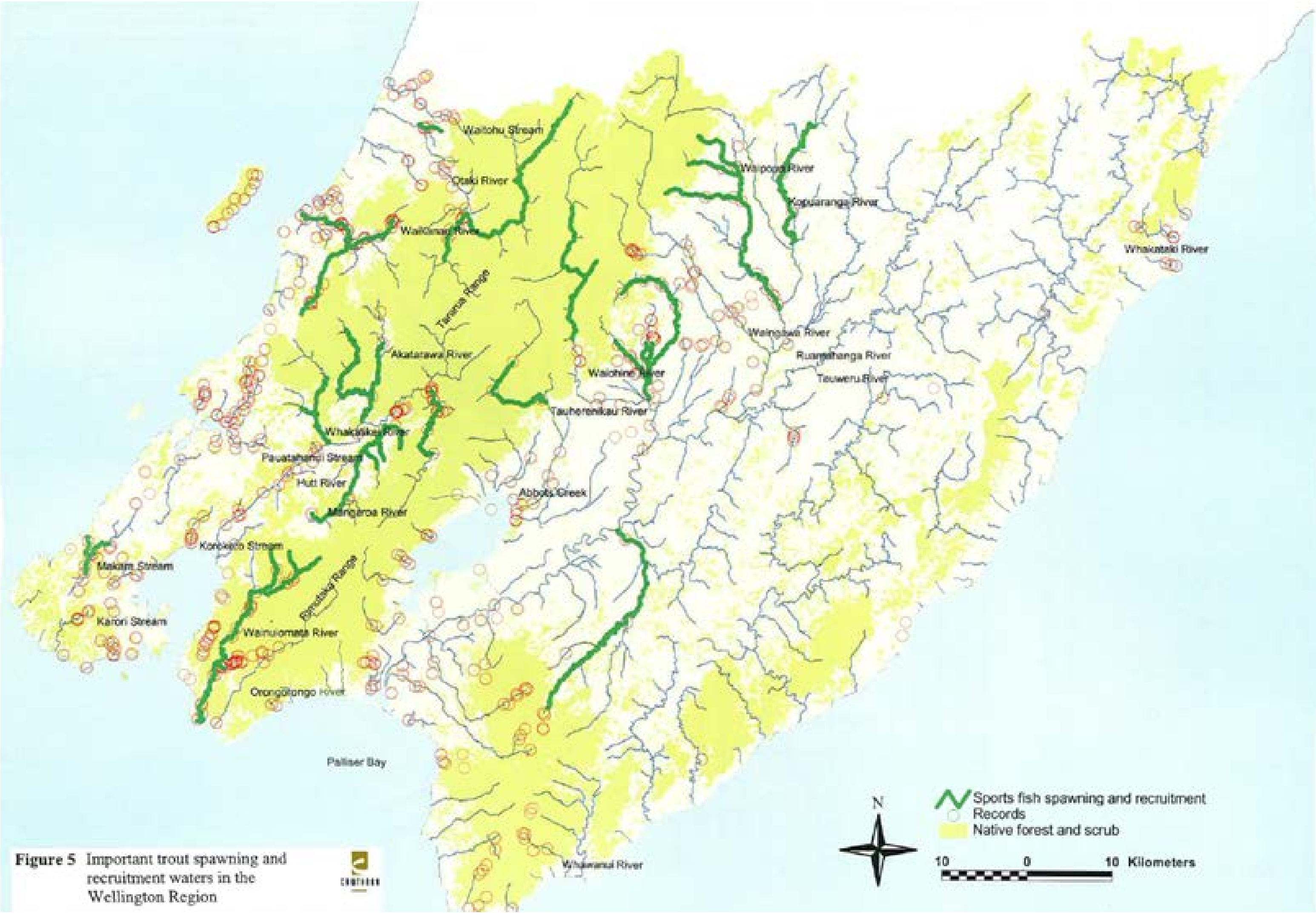

Figure 5 Important trout spawning and recruitment waters in the Wellington Region