MANGAHEKA STREAM

Assessment of Ecological Values to inform an Integrated Catchment Management Plan

Prepared for Hamilton City Council

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Executive Summary

Hamilton City Council (HCC) is preparing an Integrated Catchment Management Plan (ICMP) for the Mangaheka Stream catchment. Mangaheka Stream is a small tributary of the Waikato River located north of Hamilton City. The southern part of the catchment has been, or will be, converted from rural to industrial/employment land use. The recently completed Waikato Expressway and connecting roads also pass through the south western portion of the catchment.

This ecological assessment has been prepared to support ICMP development. The assessment characterises the state of the stream receiving environment in the context of the wider rural catchment and existing impact. The assessment also identifies the risks and sensitivities of the stream with respect to industrial and road stormwater discharges managed for attenuation and treatment to TP10 standards as a minimum.

Based on field surveys and review of existing information, the Mangaheka Stream has the following characteristics:

- The stream headwaters are artificial drains, which discharge into the modified stream main stem within a surface flow path, before becoming a natural stream channel north of Horotiu Road.
- In the upper catchment drain networks, aquatic habitat quality provides poor conditions for biota, and indigenous fish diversity is naturally limited by intermittent flow and lack of riparian cover.
- In the middle stream catchment, aquatic habitat quality provides moderate conditions for biota, and the indigenous fish community is more diverse although aquatic macroinvertebrate diversity is poor throughout the catchment.
- Water quality is typical of groundwater-fed rural Hamilton streams with some water quality parameters exceeding the tolerances of aquatic species. Concentrations of total copper and zinc exceed ANZECC guidelines, and nutrients are elevated. The toxicity of metals is likely to be limited by formation of mineral complexes with phosphorus and organic material, meaning the bioavailable dissolved form of metals in the water column is low.
- Benthic sediment has elevated arsenic concentrations at Te Kowhai Road but this is likely to be a localised issue and does not exceed ANZECC guidelines.
- The drains provide habitat for shortfin eels, and threatened longfin eels and black mudfish (Goodman *et al.* 2013). The stream provides habitat for shortfin eels and banded kokopu, and threatened giant kokopu and longfin eels (Goodman *et al.* 2013). The presence of threatened species which confers ecological significance on the catchment.

In the context of TP10 stormwater design principles and the contaminant load assessment [CONFIRM], the risks and sensitivities of the Mangaheka Stream catchment have been identified with objectives and actions as follows:

- There is potential for stormwater discharges to change downstream drain hydrology from intermittent to perennial, reducing the habitat value for black mudfish that rely on intermittent flows to avoid eel predation pressure. This can be avoided by maintaining extended detention volumes to avoid continuous flows into the downstream drains from stormwater treatment devices.
- There is potential for thermal pollution from stormwater discharges to cause adverse effects downstream, even with TP10 devices installed for stormwater treatment. Open water areas should be avoided in treatment devices and wetland plant cover maximised. Where existing devices have low wetland plant cover, supplementary planting should be undertaken to reduce potential thermal effects.
- The unavoidable increase in discharged stormwater volume has potential to cause bank instability in downstream drain networks, particularly where drain banks are steep and unvegetated. Preventative measures should be implemented in conjunction with landowners and Waikato Regional Council to armour bank sediments.
- There is potential for ecologically significant fish habitat within the Rotokauri Structure Plan employment zone to be affected by development. Mitigation or offset of this effect should be managed in conjunction with Waikato Regional Council to provide fish passage into new habitats or replacing the removed habitats elsewhere in the catchment.
- The performance of treatment devices must be monitored to ensure that they achieve the design standards set.
- Existing riparian vegetation is providing an important role for water cooling and bank stability. Where riparian or aquatic vegetation has been, or will be removed, it should be replaced to reduce effects on water and habitat quality, and bank stability.

A monitoring regime is recommended to ensure that the objectives set to maintain and/or enhance the ecological values of the Mangaheka Stream are achieved.

1.0 Introduction

Boffa Miskell Ltd (BML) was engaged by Hamilton City Council (HCC) to assess the ecological values of the Mangaheka Stream to support the development of an Integrated Catchment Management Plan (ICMP). The Mangaheka Stream is a small rural catchment located on the northwest periphery of Hamilton draining in a northwest direction to its outlet into the Waipa River.

Before development, the Mangaheka Stream upper catchment was comprised of two small drain networks within HCC boundaries joined at a confluence immediately downstream of Koura Drive. This very flat land with poorly defined catchment boundaries was serviced by drains excavated to reduce shallow groundwater levels to allow rural land use (mainly for cropping).

Within HCC boundaries, the catchment includes the 177ha Rotokauri Structure Plan industrial area between the Waikato Expressway and the North Island Main Trunk railway and an employment zone between the Expressway and Burbush Road/Koura Drive. More than 120ha of industrial land in this area has been developed since 2012. Farm drains have been replaced with stormwater treatment swales and detention basins with discharge points into the downstream drain network. The Waikato Expressway and connecting roads was constructed with stormwater treatment swales discharging into existing, new and realigned drains within the Mangaheka catchment.

Downstream of Koura Drive within Waikato District, the Mangaheka Stream has a rural catchment (mainly dairy farming or grazing) comprised of artificial drains, modified stream, and an extensive gully wetland. The adjacent catchments are Te Rapa Stream to the east (discharging into the Waikato River) and Lake Rotokauri to the west (discharging to the Waipa River).

The purpose of this assessment is to determine the existing values of the waterway, including ecological values and habitat. Further, the assessment evaluates whether land development and stormwater discharges into the waterway from existing and proposed industrial/employment areas and roading may have actual or potential effects, and how far downstream those effects (if any) would be expected to be measurable.

This ecological assessment has been prepared to set clear objectives for the Mangaheka Stream catchment that will be achieved by implementing Best Practicable Options (BPO). A monitoring programme can then determine whether the BPO have been effective at achieving the objectives.

1.1 Location and General Description

The Mangaheka Stream is a small tributary of the Waipa River located northwest of Hamilton City. Its catchment encompasses around 2,080ha of flat to rolling Waikato lowlands in the area generally defined by Park, Horotiu, and Onion Roads and the railway in the east, Ngaruawahia and Te Kowhai Roads in the west, and the Waikato Expressway and Tasman Road to the south (see Figure 1 in Appendix 1). The stream flows southeast-northwest towards the Waipa River.

In the upper catchment, the two main branches of drain network meet immediately downstream of Koura Drive. Prior to development, the drain networks comprised the stream headwater catchments located within the Rotokauri Structure Plan industrial/employment area, which was originally peat swamps. As a result of development of the industrial area and Waikato

Expressway designation, the drains were replaced with planted swales and detention basins. Future development is expected to result in the same waterway conversion process.

Downstream of the industrial area and Waikato Expressway, artificial farm drains flow north and northwest to Koura Drive, where they meet at the drain main stem. The drain then flows northwest through farmland before transitioning to a modified stream channel with perennial flow where natural topography forms a surface drainage channel. Outside the Hamilton City boundary, the catchment of the drains is almost entirely rural (dairy farming), comprising artificial farm drains, with very little riparian vegetation.

Between Koura Drive and Horotiu Road, the waterway is comprised of a single main stem drain or modified stream with drains discharging into it from adjacent farmland. The stream develops a more defined floodplain within an increasingly entrenched gully landform as it approaches Horotiu Road. At Horotiu Road, the road embankment and invert levels of the twin culverts dictate the groundwater levels, flood levels, and peak flows discharging downstream. Given that the culverts are perched at the downstream end, it appears that the road embankment and culverts are resulting in higher shallow groundwater levels and stream water depths than would be expected naturally. The modified stream catchment is entirely rural with almost no riparian vegetation.

Between Horotiu and Ngaruawahia Roads (SH39), the stream transitions into a large willow-dominated wetland in an entrenched gully network as a result of the road embankment impounding the stream upstream of its natural outlet to the Waipa River. Other branches of the stream form arms of the gully network at numerous confluences. The main stem flows northwest through an extensive rural (dairy farming) gully system that becomes increasingly deep and wide. The gully system is fully vegetated with a willow-dominated treeland and indigenous sedge understorey. The outlet to the Waipa River downstream of Ngaruawahia Road is via a short section of artificial drain.

Most of the Mangaheka Stream catchment is alluvial plains of the Waikato and Waipa Rivers which would originally have supported indigenous forest (Cornes *et al*. 2012). The topography and remnant vegetation indicates that the area would historically have included wetlands, particularly in low-lying flood plains and valley floors where groundwater emerges. Some of these wetlands would have included highly organic and/or peat soils, and peat swamps are known to have existed in the upper catchment.

Similar to almost all rural land in this area, by the early to mid-1900s, most wetland areas would have been drained to create farmland, and the vegetative cover changed from predominantly alluvial secondary native vegetation to exotic pasture (Nicholls 2002). Vegetation throughout the catchment is now dominated by exotic pasture with shelterbelts and shade trees associated with rural-residential and rural properties.

1.2 Development Principles and Design

The Mangaheka Stream catchment crosses several important boundaries. The upper catchment upstream of Koura Drive is within the Hamilton City boundary. The remainder of the catchment is within Waikato District. The catchment also crosses the boundary between the Central Waikato zone management plan and the Waipa zone management plan, which are WRC policy documents that drive implementation of all river and catchment management activities. However, the Mangaheka Stream is not mentioned specifically in either document. Instead, stream/drain management is driven principally by the Waikato Regional Council (WRC) Waikato Central Drainage Board sub-committee based on contractor inspections and in response to landowner concerns.

Within HCC's boundary, existing regional consents authorise treated stormwater discharges from two 60ha industrial areas into the Mangaheka Stream catchment (as the preferred alternative to discharge to adjacent catchments[1]). Detailed design of stormwater treatment and attenuation devices for the industrial areas was based on modelling undertaken for the consent process which determined that attenuation to 70% of pre-development volumes would be required to avoid downstream flooding and erosion effects[2]. The remaining land within the Rotokauri Structure Plan industrial/employment areas will be required to undertake similar modelling and design of stormwater devices and consenting processes.

The discharge consents included an adaptive management component to address uncertainties regarding downstream erosion and scour effects within the drain network resulting from additional discharge volume, recognising that the drains were stable at the time of consenting and that third party activities (landowners and Drainage Board contractors) could have unknown effects on drain bank stability.

As an adjunct to the stormwater consent process, the Mangaheka Restoration Vision was commissioned to define the restoration elements necessary to improve water quality, habitat quality, and bank stability downstream of the discharge points. This was prepared on the basis that the existing drainage district was extended to include the industrial/employment areas and that the properties within the drainage district would be levied targeted rates. These rates would then be applied to either mitigation of downstream erosion effects or implementation of the Restoration Vision in accordance with the adaptive management consent conditions. To date the drainage district extension process has not been undertaken.

The design parameters for the Waikato Expressway stormwater treatment devices [CONFIRM]

Wastewater and water supply infrastructure are expected to be provided by way of conventional water mains from a HCC reservoir and wastewater pipelines and pump stations to the HCC wastewater treatment plant.

The urbanisation activities most likely to affect aquatic ecological values as a result of continued development of the industrial and employment areas and stormwater discharges are the effects of stormwater discharges and effects of earthworks on aquatic habitats. Along with general land development earthworks, the remaining upstream extents of the farm drain networks will be filled in to facilitate land development and replaced with piped and surface stormwater infrastructure including wetlands and swales.

Ongoing operation of water and wastewater infrastructure are not expected to have a direct effect on the Mangaheka Stream catchment and are not considered further. Earthworks effects on aquatic ecosystems are expected to be addressed through regional resource consent applications and monitoring, but are considered in this assessment with regard to fish habitat.

This assessment focuses mainly on stormwater infrastructure and the ongoing effects of post-development stormwater discharges. The land uses that contribute to stormwater flows include:

- Existing industrial land and roads,
- Land under development for industrial use,
- Rural land proposed for industrial/employment zone development within the Structure Plan area, and
- Rural land.

[1] The two alternatives for stormwater discharge were to the Te Rapa Stream and to the Lake Rotokauri catchment.

[2] The stormwater model was being reviewed by HCC at the time of writing.

For the proposed industrial/employment zone development, design parameters and stormwater management have been or will be established through subdivision, land use consent, and/or discharge consent processes. This means that post-development land cover and imperviousness, design and location of stormwater infrastructure, and discharge points are, for the most part, pre-determined.

The assessment is based on the following assumptions:

- Most of the Mangaheka Stream catchment within Hamilton City will be urbanised and the headwater drains to the Structure Plan boundary will be filled in and replaced with stormwater infrastructure.
- Post-development industrial imperviousness can be expected to reflect typical modern industrial imperviousness of 85-95%, and that stormwater infrastructure has been, or will be, designed to accommodate stormwater volumes on that basis. Employment zone imperviousness can be expected to be similar or slightly less.
- No notable land use change will occur on the rural land adjacent to the Structure Plan area (defined by Koura Drive, Onion Road, Ruffell Road, and Te Kowhai Road) or in the Waikato District portion of the catchment.
- Stormwater management for all development areas is or will be designed to at least TP10[3] standards requiring an average removal of 75% of suspended sediment and associated contaminants, and stormwater volume attenuation to no less than 80% of the pre-development volume for a 1 in 10 year design rainfall event[4].
- Stormwater management for the industrial/employment areas includes onsite stormwater controls specific to the proposed site use, reticulated onsite stormwater network discharging to central wetland swale networks servicing the development, and stormwater detention devices comprised of a sediment detention basin discharging into a storage basin with a low flow area planted as a wetland for stormwater treatment or a pond. These devices will discharge to the Mangaheka Stream at Ruffell Road (existing discharge point), upstream of Waikato Expressway (existing discharge point), and at Te Kowhai Road (assumed future discharge point).
- Stormwater management for the road corridors will consist either of conventional kerb and channel flows to catchpits discharging to the swale network or diffuse surface flows to the swales.
- Fish passage will not be provided within existing industrial development since there is no upstream aquatic habitat except the detention basins.
- Fish passage may be required in future industrial/employment zone development depending on the size and significance of fish populations in remaining drain habitats.

[3] Auckland Regional Council, 2003. Stormwater Management Devices: Design guidelines manual. Technical publication 10.

[4] At the time of writing, HCC had commissioned review of existing stormwater models to confirm the appropriate volume attenuation required to avoid adverse flooding effects on downstream land.

1.3 Stormwater Discharges

The quality, volume, and flow rate of stormwater discharged from a fully urbanised area is, or will be, different to the pre-development stormwater characteristics where the catchment is comprised of both rural and urban areas.

Rural catchments are typically dominated by pervious pasture or cropping land with small areas of less pervious farm tracks and impervious hardstands, buildings and roads comprising around 1-2% of the catchment. The Mangaheka Stream has a predominantly rural catchment with a small area of rural-residential development clustered around Horotiu Road and Ngaruawahia Road. The upper catchment within the HCC boundary has 177ha within the Rotokauri Structure Plan area that has recently or will be urbanised.

When fully developed, the area within Hamilton City is expected to have typical industrial imperviousness of around 80-90%. As a proportion of the total catchment, imperviousness will continue to increase from the pre-development rural rate of around 2% to a fully developed catchment-wide imperviousness of around 9%. The increase in imperviousness will result in greater stormwater discharge volumes and flow rates than would be expected from pasture.

It is expected that the change in land use from predominantly agricultural to a higher proportion of industrial/employment zone land and/or roading will change the stormwater contaminant profile. Pre-development stormwater contaminants from rural areas typically include nutrients, sediment, turbidity, bacterial pathogens, and metals associated with agricultural use and land drainage (e.g. aluminium, iron, manganese, nickel, copper and zinc). Land drainage networks also have elevated temperatures. Industrial stormwater contaminants typically include gross pollutants, temperature, sediment, petroleum hydrocarbons, and metals. The additional mass load of contaminants from new industrial development will be partly offset by reduced rural contaminant mass loads through land use conversion and loads removed by the wetland/swale devices.

2.0 Assessment Purpose and Scope

The purpose of this assessment is to:

1. Evaluate existing aquatic ecological values, water chemistry/quality, and sediment quality of the Mangaheka Stream.
2. Identify the risks and sensitivities of the Mangaheka Stream in relation to the actual and potential effects of stormwater discharges from new and existing urban development.
3. Evaluate risks of future removal of existing drain habitat.

To provide context to the assessment, it is important to note that:

- Urbanisation to an industrial or employment land use within the HCC boundary is a foregone conclusion.
- The urbanised area will be a small proportion of the total catchment (around 8.5%).
- Agriculture is expected to remain the dominant land use within the catchment.

As set out in Table 1, this assessment has been based on surveys of riparian and aquatic habitat, biota, sediment quality and water quality present in the Mangaheka Stream. Existing information sources relating to aquatic ecology values were also evaluated.

Table 1: Data collection and methodology

Parameter	Methodology
Habitat values	Stream habitat assessment (instream and riparian qualitative assessments). Review of Land Cover Database. Review of Cornes *et al*. 2012 for identified sites of ecological significance. Review of Waikato Regional Council Regional Policy Statement and supporting technical reports regarding habitat evaluation for ecological significance.
Water quality	On-site measurement of temperature, pH, dissolved oxygen, and conductivity. Review of Waikato Regional Council water monitoring database.
Water contaminants	Water samples analysed for pH, suspended sediment, turbidity, metals, nutrients, carbonaceous biochemical oxygen demand, faecal bacteria and petroleum hydrocarbon compounds. Review of Waikato Regional Council water monitoring database.
Sediment contaminants	Sediment samples analysed for arsenic, cadmium, chromium, copper, lead, nickel, and zinc.
Aquatic macroinvertebrate fauna	Aquatic macroinvertebrate samples collected using Protocols C2 and C4 (MfE, 2001).
Fish fauna	Evaluation of Freshwater Fish Database records and fish survey.

3.0 Methods

In 2012, site reconnaissance in the Mangaheka Stream catchment identified three waterway reach types namely:

- artificial watercourses (drains) in the upper third of the catchment;
- natural/modified watercourse (stream) in the middle third of the catchment; and
- wetlands in the lower third of the catchment (Tanirau Wetland).

On that basis, four survey sites were selected for field surveys combined with stream walkover (see Figure 2 in Appendix 1). The survey sites were selected as being representative of the three reach types. The walkover and habitat assessment of the Mangaheka Stream was completed over a 3 week period from 24th April to 8th May 2012. The weather was fine with light winds and no significant rainfall had been experienced for 6 to 8 weeks prior to the assessment.

In 2016, a gap analysis of the 2012 survey data and existing data sources was completed to determine whether additional field surveys and/or analyses were required. It was determined that the 2012 survey should be repeated at similar sample sites and fish survey undertaken. This survey was completed on 19th April 2016. To allow comparison with the 2012 survey results, sites close to earlier survey sites were given preference over other locations. The weather was fine with light winds and no significant rainfall had been experienced in the week prior to sampling. During the 2016 assessment, the drains at two of the three proposed survey sites were dry or contained only stagnant water within the waterways. No data was gathered from these two sites.

The 2012 and 2016 sampling sites and 2012 walkover extents are identified on Figure 2 (Appendix 1). The 2016 surveys and updated satellite photography identified that land uses had remained largely unchanged since 2012 such that a repeat of the walkover was not necessary. The field surveys and habitat assessment of the Mangaheka Stream were completed as follows:

- The 2012 walkover assessments included observations of riparian, bank and channel vegetation, water clarity, algal cover, structures, fencing, and adjacent land use. As part of the habitat assessment, the severity and extent of erosion and scour processes was noted. This included observing whether scour and erosion is active or historic, the location of the erosion or scour (undercutting at the waterline, bank failure, sloughing of bank materials, vegetation collapse, etc.) and the likely processes causing the erosion or scour (e.g. vegetation spraying, stock treading, stock pressure at fencelines, undersized or poorly placed culverts, etc.).
- Water and sediment samples were collected from each survey site, chilled and sent to Hill Laboratories for analysis with accompanying chain of custody documentation.
- Aquatic macroinvertebrates were collected from sites with suitable habitat using a 500 µm mesh net following Protocol C4 (soft-bottomed, Quantitative – Macrophytes) (Ministry for the Environment 2001), preserved in ethanol and analysed according to Protocol P1: coded abundance. The soft-bottom Semi-Quantitative Macroinvertebrate Community Index (SQMCI-sb) was calculated for each sample (Stark & Maxted 2007).

Species richness and number of EPT[5] taxa were also calculated. The macroinvertebrate community was sampled at two sites by collecting replicate samples from similar aquatic macrophyte vegetation using Protocol C4 (MfE 2001). The locations for collection were limited by the lack of macrophyte vegetation either in the channel or on the banks over most of the drains. The two accessible locations with sufficient vegetation for sampling were at Te Kowhai Road and the Murray farm culvert. The samples were preserved with isopropyl alcohol at 75% and sent to BML for analysis. Other protocols were not used because of inadequate suitable substrate (hard substrate, woody debris, or bank overhang) and dominance of aquatic macrophytes. The soft-bottom Semi-Quantitative Macroinvertebrate Community Index (SQMCI-sb) was calculated for each sample (Stark & Maxted 2007). Species richness and number of EPT[6] taxa were also calculated. Sample collection was not possible at one site due to insufficient suitable substrate of any kind.

- Replicate aquatic macroinvertebrate samples were collected from the Horotiu survey site during the 2016 sampling round. Three replicate samples were collected using a 500 µm mesh net following Protocol C2 (soft-bottomed, semi-quantitative – Macrophytes) (Ministry for the Environment 2001), preserved in ethanol and analysed according to Protocol P3: Full count. The soft-bottom Semi-Quantitative Macroinvertebrate Community Index (SQMCI-sb) was calculated for each sample (Stark & Maxted 2007). Species richness and number of EPT[7] taxa were also calculated. The samples were preserved with alcohol and sent to Ryder Consulting for analysis.
- Due to low water levels, only one site was suitable for fish survey in 2016. Fish survey methods used are shown in Table 2. The range of habitats was representative of that found on the Mangaheka Stream and considered the most likely fish capture locations.

Table 2: Fish Survey Methods

Methods	Horotiu Road
Fyke nets	✓
Gee's minnow traps	✓
Kilwell bait nets	✓

Five baited fyke nets were set upstream of the culvert beneath Horotiu Road. Six baited Gee's minnow traps and six baited bait traps were also set interspersed between the fyke nets. The nets were deployed in the afternoon and retrieved the following morning. All fish caught were identified, measured, and released, except for pest fish, which were disposed of humanely.

A single electric fishing survey was conducted along the Horotiu sample reach. Due to the depth of water levels and abundance of aquatic weed, electric fishing was not an effective means for measuring fish abundance/diversity over the surveyed stream reach.

A review of the NIWA Freshwater Fish Database was carried out for surveys undertaken on the Mangaheka Stream and adjacent waterways.

[5] EPT: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), the most sensitive aquatic macroinvertebrate species indicative of good water quality and habitat.

[6] EPT: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), the most sensitive aquatic macroinvertebrate species indicative of good water quality and habitat.

[7] EPT: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), the most sensitive aquatic macroinvertebrate species indicative of good water quality and habitat.

4.0 Results

4.1 Habitat Values

4.1.1 Site Context

The Mangaheka Stream catchment is located within the Waikato Ecological Region and the Hamilton Ecological District. The indigenous vegetation of the Hamilton Ecological District is severely depleted, with only 1.6% of the original native vegetation remaining and at least 20% of its indigenous flora threatened or extinct (Clarkson & McQueen 2004). Almost all of the original alluvial floodplain vegetation and swamps of the Waikato lowlands have been cleared and drained for farming (Nicholls, 2002). The Mangaheka Stream lower catchment is different in this respect with additional wetland area inadvertently created in the gully upstream of Ngaruawahia Road. Within Hamilton City, there is less than 20 hectares of high quality indigenous habitat remaining (Clarkson & McQueen, 2004), although substantial restoration is occurring. Restoration is also proposed for the Tanirau Wetland in the Mangaheka Stream lower catchment in Waikato District.

The Lands Environments of New Zealand (LENZ) database classifies most of the Mangaheka Stream catchment as Environment A5.3 which is comprised of poorly-drained peat soils of low to very low fertility or Environment A7.2 comprised of imperfectly drained soils of low fertility. There are very small patches of Environment F6.1 which is comprised of mid-age well drained soils of low fertility from rhyolitic tephra, outcropping mainly at Horotiu Road and around the Onion Road ridgeline.

4.1.2 Terrestrial Vegetation

The terrestrial flora within the Mangaheka Stream catchment mirrors the situation in the surrounding areas. Historic vegetation cover was secondary succession alluvial vegetation (Nicholls 2002), most likely kahikatea swamp forest, with mixed conifer-broadleaf forest on higher ground (Clarkson *et al*. 2007, Cornes *et al*. 2012). Extensive areas of peat bog vegetation (Clarkson *et al*., 2007) and lowland swamp vegetation have been present in the flat upper catchment, with variable drainage downstream to waterways of the three adjacent catchments.

Today, the area is almost entirely vegetated in exotic pasture grasses or crops. Larger trees and shrubs are limited to exotic species planted as shelterbelts, or for amenity and animal welfare purposes (livestock shade). Plate 1 below shows the typical vegetation cover throughout the catchment, consisting of pasture or crops and exotic trees/hedges. Within the stream floodplain in the middle reach, the vegetation also includes scrub (blackberry etc.), rushland/sedgeland, and willow weed associated with damp, poorly drained soils. In the lower catchment, pasture and willow weed extends to the margin of the gully wetlands. Apart from indigenous rushes and sedges in pasture, indigenous plants are virtually non-existent.

Plate 1: Mangaheka Stream – typical catchment vegetation

In the upper and middle reaches, there is typically limited riparian vegetation adjacent to the waterways (see Plates 1 and 2). Although most waterways have no canopy cover, some have cover from shelterbelt trees comprised of Lawson's cypress, hawthorn, privet, gorse, blackberry or barberry. Some fenced drains have margins that are not maintained (e.g. sprayed) and riparian vegetation is comprised of rank grass, mixed native and exotic rushes, herbaceous weeds (buttercup, willow weed, dock, etc.) and occasional shrub/vine weeds such as gorse, broom, pampas, and blackberry. However, much of the waterway is fenced at the bank crest and periodically sprayed so riparian vegetation is very limited.

In general, native plants are only rarely present beneath exotic shrubland or trees or as planted specimens. However, as the stream approaches Horotiu Road, there is increasing cover of tall sedges (*Carex lessoniana/geminata*) and rushes associated with swampy ground where stock access is more limited as shown in Plate 2 below.

Plate 2: View downstream near Horotiu Road, showing Carex sedgeland and rushes on swampy true left bank.

In the lower catchment, the riparian vegetation consists of wetland vegetation with a canopy dominated by grey willow (*Salix cinerea*), with understorey vegetation comprised variously of *Carex* sedgeland and other species as described in Section 4.1.4.

The most recent vegetation survey within Hamilton City did not identify any key ecological sites of significance within the Mangaheka Stream upper catchment (Cornes *et al*. 2012). Using the criteria of Cornes *et al*., vegetation observed in the Tanirau Wetland would be considered significant but is outside Hamilton City. Cornes *et al*. has not identified any other key ecological sites with connectivity to the Mangaheka Stream catchment.

4.1.3 Aquatic Habitat – Drains

From northwest of Avalon Drive to approximately midway between Ruffell Road and Horotiu Road, the watercourse type is an artificial watercourse (drain). The drains were excavated to drain historic wetlands and high groundwater/springs in the upper catchment to facilitate pasture development for farming. Pre-development soils show the upper catchment wetlands were peat swamps, and it is likely that peat lenses are present as subsoil layers influencing pH and water chemistry throughout the upper catchment. The drains are characterised by steep banks, straight channels, uniform channel morphology and ephemeral flows with standing water during dry periods.

The drains provide poor habitat for fish and aquatic macroinvertebrates, with slightly better aquatic habitat associated with shelterbelt or dense riparian plant cover. Water depths vary considerably depending on historic drain maintenance. Some dish channels and drains through or between paddocks are shallow and likely to be continuously dry except immediately after rainfall. Few of the drains have natural surface drainage and most are fed predominantly by groundwater. The drain main stem does not have perennial flow. It dries up and retains pools of water as potential habitat refuges during dry periods when groundwater levels drop. The drain dimensions vary considerably from place to place, from 0.75m to 2.5m wide, and 0.5m to 2.8m channel depth. Water depth can vary considerably from no water to around 0.3-0.5m deep. Bed sediment is uniformly soft sediment, typically silt and clay with sand where the channel is cut through pumice sand layers.

All the drains have poor habitat diversity (see Plate 3 below), with uniform width and depth, few pools, very little woody debris, poor water clarity, and minimal stable habitat, shade or riparian vegetation. There are no debris jams and no notable physical fish passage barriers. However, low or no flow, high temperatures, low dissolved oxygen, and very poor water clarity are likely to present fish passage barriers.

Plate 3: Mangaheka Stream typical drain habitat

Depending on Drainage Board activities, there are times when drain riparian vegetation has been sprayed over substantial drain lengths. Because of the low cohesion of the underlying soils and bank steepness, vegetation removal has been observed to result in widespread bank slumping compared with unsprayed banks on which erosion and slumping are noticeably less.

Landowners indicate that, prior to the construction of the Waikato Expressway and Koura Drive, the drains only flooded during extreme events. Subsequently, relocation of some drains has resulted in localised flooding after rainfall events.

4.1.4 Aquatic Habitat – Modified Stream

From midway between Ruffell Road and Horotiu Road, the watercourse enters undulating topography and a defined gully system that becomes deeply incised over a short distance with a wide floodplain and steep gully walls. The watercourse type is a modified stream and has a relatively natural channel with reaches where historic straightening has occurred.

From approximately 1,200m upstream of Horotiu Road, the gully intersects the groundwater table as evidenced by large springs and seeps discharging from the gully toe and floodplain throughout the gully system. This contributes to progressively increasing base flows with distance downstream. The stream dimensions vary considerably from place to place, typically from 1.5m to 2.5m wide, and 0.75m to 2.0m channel depth. However, some pools can measure up to 6m wide, with channel depth close to 2.5m where scour downstream of a culvert has changed channel morphology. Water depth can vary considerably from no water to around 0.3-1.0m deep. Bed sediment is uniformly soft sediment, typically silt and clay with sand where the channel is cut through pumice sand layers.

Riparian vegetation consists predominantly of rank pasture with some areas of indigenous sedges and ferns, particularly where large springs preclude grazing. Landowners indicate use of the floodplain upstream of Horotiu Road is generally limited to summer grazing because the springs make ground conditions too boggy for stock access.

The stream has poor to moderate habitat diversity (see Plate 4 below), with diversity increasing with distance downstream. Typically the stream has uniform width but variable depth, with occasional pools. There is a small amount of organic debris from riparian vegetation, but little woody debris and minimal to moderate stable habitat depending on riparian conditions. Some shade is provided by the banks and aquatic macrophytes, toe undercutting, and riparian vegetation, but water clarity is poor.

Plate 4: Typical modified stream reach at upstream extent south of Kay Road.

Depending on Drainage Board activities, there are times when stream riparian vegetation has been sprayed over substantial lengths. Because of the low cohesion of the underlying soils and bank steepness, vegetation removal has been observed to result in widespread bank slumping compared with unsprayed banks on which erosion and slumping are noticeably less. Erosion repair responses in this reach have included deposition of rock riprap into slumped areas. This has caused further bank collapse and diversion of flows to adjacent banks where toe undercutting and slumping subsequently occurs.

There are no debris jams causing fish passage barriers. Collapsing lobes of riprap and bank sediment may form temporary fish passage barriers. The twin culverts at Horotiu Road are perched and could provide a fish passage barrier to non-climbing fish species, although non-climbing species (black mudfish) have been found upstream.

Plate 5: Rock armouring collapsing into the stream

Landowners observe the depth and frequency of flooding increases with distance downstream. At Horotiu Road, the flood depth can exceed 1.5m and floods the gully floor up to 4 times per year, with smaller floods escaping the stream banks between 5 and 10 times per year. Downstream of Horotiu Road close to the swamps, the flood height can reach 2.0-2.5m.

At the time of the 2012 assessment, bank failure was severe in some places as shown in Plate 5 below. There was one property on which the channel was mostly unfenced so cattle access was unrestricted and stock treading affected bank failure. However, fencing was in progress and this erosion is expected to have largely ceased as a result. In other places, as shown in Plate 5, fencing too close to the bank crest is contributing to bank instability.

Plate 6: Modified stream reach bank instability. Note also the iron staining from groundwater inflows at the waterline.

4.1.5 Aquatic Habitat – Wetland

From approximately 820m downstream of Horotiu Road to Ngaruawahia Road (SH39), the watercourse becomes a wetland (specifically a lowland shrub – sedge swamp[3]) within a rolling to very steep gully. The watercourse varies considerably depending on the characteristics of the wetland at any given location. The wetland has standing water, multiple flowing channels (leads), and numerous large seeps and springs flowing into the wetland around the flood plain and gully walls. The channel appears to be almost entirely natural with little historic modification. However, as noted earlier, it is likely that partial impoundment of the stream channel occurred as a result of the SH39 road embankment construction and culvert invert levels, resulting in a wetland environment replacing the former stream environment.

A survey of the wetland vegetation was not undertaken. Observations of the vegetation downstream of Horotiu Road, Crawford Road, and Ngaruawahia Road indicate the vegetation generally consists of a canopy dominated by grey willow (*Salix cinerea*) with an understorey of indigenous sedges (*Carex virgata, Carex geminata*) and a minor component of indigenous trees and shrubs (*Coprosma* species), mahoe (*Melicytus ramiflorus*), mamaku (*Cyathea medullaris*), cabbage trees (*Cordyline australis*) and kahikatea (*Dacrycarpus dacrydioides*)). The gully is very densely vegetated and the vegetation is likely to provide almost 100% shade over most of the wetland leads.

It is likely that the wetland floods frequently but because the wetland is largely inaccessible, it is unlikely that floods affect the use of the area. Floods occasionally restrict or prevent access across farm access tracks. While there are likely to be occasional debris jams within the wetland associated with tree fall, given the multiple wetland leads, obstruction of fish passage is unlikely to occur.

This wetland catchment provides high quality aquatic habitat with high habitat diversity, woody debris, almost complete channel shade, and almost completely stable habitat.

Plate 7: Typical stream reach downstream of Crawford Road through the wetland.

4.2 Water Quality

4.2.1 Standards for Water Quality

The Waikato Regional Plan rules for stormwater discharges refer to the ANZECC 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality as one of the standards against which hazardous substances in stormwater are to be assessed in order to achieve the conditions associated with the relevant rule.

HCC was granted a comprehensive consent from WRC for the discharge of stormwater from its urban area. The comprehensive consent conditions refer to the USEPA (United States Environmental Protection Agency) National Recommended Water Quality Criteria as the standard which the concentration of hazardous substances in discharges are required to meet.

Based on correspondence with WRC staff, we understand that the USEPA criteria are considered more appropriate than the locally derived ANZECC criteria because they reference the dissolved fraction of stormwater contaminants (specifically metals such as copper, lead and zinc) and provide standards for acute (short-term) exposure as well as chronic (long-term) exposure. NIWA and WRC considered the dissolved fraction of contaminants to be more relevant to the toxicity effects experienced by water column-dwelling biota exposed to stormwater discharges compared to total concentrations which includes the particulate fraction. Acute exposure is considered to be more relevant to the intermittent rain event-derived nature of stormwater discharges.

However, given that the purpose of this assessment is to establish the existing quality of the environment, not the impact of specific stormwater discharges, it is appropriate to assess existing water quality against the ANZECC guidelines on the basis that they set thresholds for chronic exposure of aquatic organisms to existing contaminants.

4.2.2 Results

A results summary is presented below in Table 3 and laboratory reports are provided in Appendix 2. In Table 3, the results are compared against the guideline values noted in the footnotes. Results in bold and shaded exceed the guideline value. Results in bold only are values that are elevated but for which there is no guideline value. The range of analytes was less in 2012 compared with 2016, but due to the lack of water flow it was not possible to repeat water sampling across all the sites. No Data (denoted as ND in Table 3) indicates that analysis for that parameter was not undertaken in 2012.

The lack of drain samples in 2016 precludes a current assessment of the impact of land drainage on water quality. However, results are compared with BML water quality data from five other Hamilton catchments to assess likely water quality in drain flows.

A multifunction water quality meter was used to determine in-stream pH, temperature, and dissolved oxygen during both the 2016 assessments, but was not functioning correctly in 2012. Seasonal variations in these parameters are discussed below.

Table 3: Water Sample Analysis

Analytes	**Units**	**Site 1** **Ruffell Rd**	**Site 2** **Te Kowhai Rd**	**Site 3** **Farm Culvert**	**Site 4** **HJV Boundary**	**Site 5** **Horotiu Rd**	**Guideline Values**
Water Quality							
Temperature	°C	10.6	11.4	11.4	12.7	15.7	
pH (Hills Laboratory)	pH Units	6.5	6.4	6.4	5.8	6.9	6-9 [8]
pH (on site – 2016)	pH Units	ND	ND	ND	ND	7.3	6-9 [8]
Conductivity (on site – 2016)	µs/cm	ND	ND	ND	ND	132.8	-
Dissolved oxygen (on site)	mg/L	47.8	30.5	63.1	26.2	44.0	-
Turbidity	NTU	**18.2**	**18**	**23**	**12.9**	6.2	-
Total Suspended Solids	g/m^3	10	13	13	6	5	-

[8] Australian and New Zealand Environment and Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand. 2000. Australian and New Zealand Guidelines for Fresh and Marine Waters Quality. Trigger values for aquatic ecosystem protection at 90% protection of species, based on a highly disturbed system as indicated by the aquatic macroinvertebrate community composition.

Analytes	Units	Site 1 Ruffell Rd	Site 2 Te Kowhai Rd	Site 3 Farm Culvert	Site 4 HJV Boundary	Site 5 Horotiu Rd	Guideline Values
Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	g O2/m3	<2	<2	<2	<2	<2	-
Faecal Coliforms	cfu/100mL	**430**	**700**	**900**	**1,100**	**410**	100 [9,10]
Metals							
Dissolved Aluminium	g/m^3	ND	ND	ND	ND	0.010	0.08 [8]
Total Aluminium	g/m^3	ND	ND	ND	ND	0.022	0.08 [8]
Dissolved Arsenic	g/m^3	ND	ND	ND	ND	<0.0010	0.094 [8]
Total Arsenic	g/m^3	ND	ND	ND	ND	<0.0011	0.094 [8]
Dissolved Cadmium	g/m^3	ND	ND	ND	ND	<0.00005	0.0004 [8]
Total Cadmium	g/m^3	ND	ND	ND	ND	<0.000053	0.0004 [8]
Dissolved Chromium	g/m^3	ND	ND	ND	ND	<0.0005	0.006 [8]
Total Chromium	g/m^3	ND	ND	ND	ND	<0.00053	0.006 [8]
Dissolved Copper	g/m^3	ND	ND	ND	ND	<0.0005	0.0018 [8]
Total Copper	g/m^3	**0.0022**	**0.0028**	**0.0026**	**0.0025**	<0.00053	0.0018 [8]
Dissolved Iron	g/m^3	ND	ND	ND	ND	0.91	-
Total Iron	g/m^3	1.04	1.61	1.87	2.1	2.4	-
Dissolved Lead	g/m^3	ND	ND	ND	ND	<0.00010	0.0056 [8]
Total Lead	g/m^3	0.00032	< 0.00011	0.00019	0.00024	<0.00011	0.0056 [8]
Dissolved Nickel	g/m^3	ND	ND	ND	ND	<0.0005	0.013 [8]
Total Nickel	g/m^3	ND	ND	ND	ND	<0.00053	0.013 [8]
Dissolved Zinc	g/m^3	ND	ND	ND	ND	<0.0010	0.015 [8]
Total Zinc	g/m^3	**0.069**	**0.023**	**0.033**	**0.0175**	0.0012	0.015 [8]
Nutrients							
Total Nitrogen	g/m^3	**4.2**	**2.5**	**4.6**	**1.66**	**0.44**	0.04-0.10 [11]
Total Kjeldahl Nitrogen	g/m^3	**1.08**	**1.12**	**1.21**	**1.14**	**0.38**	0.04-0.10 [11]
Total Ammoniacal N	g/m^3	ND	ND	ND	ND	0.064	1.43 [8]
Nitrite N	g/m^3	ND	ND	ND	ND	0.004	0.04-0.10 [11]
Nitrate N	g/m^3	ND	ND	ND	ND	**0.055**	0.04-0.10 [11]
Nitrate-N + Nitrite-N	g/m^3	**3.1**	**1.39**	**3.4**	**0.52**	**0.058**	0.04-0.10 [11]

[9] Australian and New Zealand Environment and Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand. 2000. Australian and New Zealand Guidelines for Fresh and Marine Waters Quality. Livestock drinking water guidelines – Faecal coliforms.

[10] Ministry for the Environment 2003. Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment, Wellington.

[11] Ministry for the Environment, 1992. Water Quality Guidelines No. 1: Guidelines for the Control of Undesirable Biological Growths in Water.

Analytes	Units	Site 1 Ruffell Rd	Site 2 Te Kowhai Rd	Site 3 Farm Culvert	Site 4 HJV Boundary	Site 5 Horotiu Rd	Guideline Values
Dissolved Reactive Phosphorus	g/m^3	0.005	0.012	0.007	0.005	0.005	0.015-0.03[11]
Total Phosphorus	g/m^3	**0.056**	**0.106**	**0.077**	**0.058**	**0.035**	0.015-0.03[11]
Hydrocarbons							
PAHs	g/m^3	ND	ND	ND	ND	ND	-
Total Petroleum Hydrocarbons C7-C36	g/m^3	<0.7	<1.4	<1.4	<0.7	<0.7	-

The Mangaheka Stream has water chemistry very similar to other rural waterways around Hamilton. The iron flocs observed throughout indicate a strong inflow of anaerobic groundwaters, sourced predominantly from wetland or peat deposits. Observations indicate that the groundwater contribution to watercourse baseflow increases rapidly with distance downstream as evidenced by the increase in flow rate and volume and the continued discharge of springs and seeps from the incised gully toe, even after an dry period of several months from January 2012 when soil moisture deficit was high and surface flows were minimal or absent.

4.2.2.1 Sediment/Turbidity

Being a groundwater-fed stream originating in relatively flat terrain, suspended sediment concentrations are low, but observations at Horotiu Road indicate suspended sediment increases rapidly after rainfall so suspended sediment spikes are likely to be common. As is typical for rural streams within this land type, low suspended solids concentrations do not always reflect turbidity, indicating that elevated turbidity is influenced by sources other than sediment. The observed orange staining and iron flocs are likely to be contributing (in part) to elevated turbidity, supported by elevated iron concentrations. There is no guideline value for total iron. Although not analysed, it is expected that concentrations of manganese would be similarly elevated and contributing to turbidity. Other reasons for elevated non-sediment turbidity are discussed below.

Although there is no guideline value for turbidity, the ANZECC Guidelines refer to research into banded kokopu avoidance behaviour at turbidity of 20NTU and WRC water quality scientists typically use turbidity of 10NTU or suspended sediment concentration of 10g/m^3 as the threshold above which recreational and ecological effects occur. Turbidity was above 10NTU at all sites in 2012 which is typical of rural streams around Hamilton draining peat/organic wetland soils.

4.2.2.2 Metals

The 2016 sample had very little land drainage inputs since the upstream drainage network was dry. Based on the available Mangaheka results and the results from all other Hamilton catchments, the Mangaheka metals concentrations are very likely to mirror that of other Hamilton catchments when drains are flowing as follows:

- Arsenic, cadmium, chromium, lead, and nickel generally below ANZECC guidelines.
- Aluminium, copper, and zinc exceeding ANZECC guidelines.

- Iron is elevated.

Based on the results in other catchments, phosphorus can be expected to complex with aluminium, iron, manganese, zinc, copper and other metals forming metal phosphates, increasing turbidity, reducing nutrient availability and limiting metal bioavailability and therefore toxicity in the water column.

Concentrations of total copper and total zinc exceed ANZECC guidelines indicating potential for biological harm, but concentrations of the bioavailable dissolved fraction are likely to be below ANZECC thresholds.

Because there was little urban stormwater being discharged into these waterways prior to or at the time of sampling, metals are likely to be from agricultural or groundwater sources as a result of land drainage. This is supported by the average total copper, lead, and zinc concentrations being very similar to the median total concentrations of 28 samples taken at 20 rural waterways close to Hamilton[12], each with little or no urban stormwater discharges.

It is considered likely that elevated metals are a normal water quality component resulting from land drainage. Metals complexes may have localised impacts on dissolved oxygen concentrations, especially where iron discharges occur.

4.2.2.3 Nutrients

Elevated concentrations of nitrogen and phosphorus are ubiquitous in waterways around Hamilton, and generally far exceed the Ministry for the Environment water quality guidelines required to limit algal growth. However, the Mangaheka catchment has the lowest phosphorus concentrations of the Hamilton catchments with concentrations of total and dissolved phosphorus well below the median concentrations. Nitrogen concentrations were also among the lowest of the Hamilton catchments. With respect to algal growth, the sequestration of phosphorus into metal phosphates and the predominance of particulate phosphorus may limit bioavailable phosphorus to concentrations below that required for algal growth to some extent.

However, filamentous algal growth was observed frequently throughout the drain reaches during site assessment but was not observed in the modified stream reaches or wetlands. Filamentous algal growth was most noticeable where aquatic macrophytes had recently been sprayed and in reaches downstream of this.

4.2.2.4 Faecal Pathogens

Elevated faecal coliform levels are ubiquitous in waterways around Hamilton regardless of their catchment land uses, although rural drains tend to have lower levels than urban waterways. In the Mangaheka catchment, faecal coliforms exceed ANZECC guidelines for livestock watering and Ministry for the Environment guidelines for human contact at all sampling sites and the average for Mangaheka sites is close to the median for all Hamilton streams.

4.2.2.5 Water Quality

Petroleum hydrocarbons and carbonaceous biochemical oxygen demand (CBOD) were not detected. However, given the agricultural land uses, it is likely that CBOD fluctuates in response to inputs of organic matter. A preliminary (2011) water sample taken in the Ruffell Road drain adjacent to maize cropland had concentrations of CBOD at almost 5 times the guideline so it is likely that CBOD fluctuates substantially in response to inputs of organic matter associated with crop harvesting.

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[12] BML unpublished data, 2012 – 2015.

Temperature and dissolved oxygen will experience diurnal and seasonal fluctuations. Water temperature was cool (10.6 – 15.7°C) at the time of sampling, but observations indicate that summer water temperatures will exceed thermal tolerances of aquatic fauna throughout the upper catchment drains where riparian cover is limited and water depth is shallow. The open water areas in swales and detention basins in the industrial area are likely to experience ongoing elevated turbidity and suspended sediment loads. This may result in thermal storage causing temperatures exceeding 20°C during summer and low dissolved oxygen concentrations downstream of the discharge points.

In the modified stream channel where the stream has perennial groundwater-sourced baseflow and riparian vegetation cover, water temperature is likely to remain below the thermal tolerances of most fish and aquatic macroinvertebrate species.

4.2.3 Contaminant Load Assessment

A contaminant load assessment (CLA) has been carried out by Morphum Environmental Ltd (DATE). The contaminant inputs for industrial/employment zone land uses were based on the specific yields given in NIWA (2001) [CONFIRM] modified by the Brough *et al.* results where appropriate for metals concentrations [CONFIRM].

The results of the CLA indicate that use of the various means of compliance as set out in Figure B2 to treat stormwater will maintain/increase/decrease concentrations of metals and sediment [below/above] ANZECC guideline values for biological harm [CONFIRM]. Further, assuming the means of compliance perform to expectations following development, Table A1 shows that contaminant concentrations and yield will generally be [lower/higher] than the existing environment [CONFIRM].

DETAIL TO COME...

4.3 Sediment Quality

A results summary is presented below in Table 4 and full laboratory reports are provided in Appendix 2. In Table 4, the results are compared against the ANZECC 2000 Interim Sediment Quality Guidelines (ISQG) as noted in the footnotes. Results in bold and shaded equal or exceed the guideline value.

Table 4: Sediment Sample Analysis

		2012 Pre-development				2016	
Analytes	**Units**	**Ruffell Rd**	**Te Kowhai Rd**	**Farm Culvert**	**HJV Boundary**	**Horotiu Rd**	**ISQG - Low Guideline Values[13]**
Total Recoverable Iron	mg/kg	6,100	37,000	16,300	12,300	-	-
Total Recoverable Arsenic	mg/kg	5	**20**	12	13	8	20
Total Recoverable Cadmium	mg/kg	< 0.10	1.05	0.23	0.38	0.16	1.5
Total Recoverable Chromium	mg/kg	4	10	6	7	3	80

[13] Australian and New Zealand Environment and Conservation Council; Agriculture and Resource Management Council of Australia and New Zealand. 2000. Australian and New Zealand Guidelines for Fresh and Marine Waters Quality. Interim sediment quality guidelines.

Total Recoverable Copper	mg/kg	4	51	9	26	2	65
Total Recoverable Lead	mg/kg	4.9	15.7	12.3	14.1	3.2	50
Total Recoverable Nickel	mg/kg	2	7	3	3	<2	21
Total Recoverable Zinc	mg/kg	28	162	54	33	34	200

Except for arsenic, the concentration of all metals is below the ISQC-Low trigger concentrations. The arsenic concentrations equal the ISQC-Low concentration indicating the potential for adverse effects on benthic biota. Although the Te Kowhai road sediment has the highest concentrations of contaminants in sediment, there is no indication of risk to people or livestock.

4.4 Aquatic Macroinvertebrates

The full macroinvertebrate analysis reports are provided in Appendix 3 and the summary table is shown below.

Table 5: Macroinvertebrate Sample Analysis

Metric	2012 Pre-development		2016
	Farm Culvert	**Te Kowhai Rd**	**Horotiu Rd**
Total Abundance	180	470	320
Taxonomic richness	18	25	12.7
No of EPT Taxa	1	1	1
%EPT abundance	12.2	0.2	13
MCI–sb	50.3	71.8	54.5
QMCI–sb	2.6	3.2	1.7

In 2012, the macroinvertebrate community was characterised by high abundance and moderate diversity, with the dominant fauna comprising Oligochaete worms, Diptera larvae and snails. Other fauna present included flatworms, dragonflies and caddisflies in low numbers. A total of 32 taxa were identified (8 at the farm culvert, 16 at Te Kowhai Road), including only two sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa. Although the two sites had quite different macroinvertebrate communities, both were characterised by low Macroinvertebrate Community Index (MCI-sb/QMCI-sb) scores of 50.6/2.6 for the farm culvert and 71.8/3.2 for Te Kowhai Road. This reflects the low abundance of sensitive taxa and indicates probable severe pollution.

The 2016 macroinvertebrate samples were dominated by flatworms, with caddisflies (*Oxyethira albiceps*) also featuring prominently. Other fauna present in relatively high numbers included species of crustaceans and molluscs. Similar to 2012, a total of 19 taxa were identified at the Horotiu Road site, including only one EPT taxa which is tolerant. Similar to the 2012 results, the Macroinvertebrate Community Index (MCI-sb/QMCI-sb) scores of 54.5/1.7 reflect the low abundance of sensitive taxa and indicates probable severe pollution.

4.5 Fish

In the Waipa River catchment, 14 native fish species have been recorded (Speirs 2001). The NIWA Freshwater Fish Database (FFDB) contains 14 records for fish surveys at 7 sites undertaken from 1984 to 2016 in the Mangaheka Stream. Survey locations included Crawford Road, Horotiu Road, and within the Structure Plan area drains. As shown in Figure 5, five species were identified including one exotic species (mosquitofish) and four native species namely shortfin eel (*Anguilla australis*), longfin eel (*Anguilla dieffenbachii*), banded kokopu (*Galaxias fasciatus*), and black mudfish (*Neochanna diversus*). Black mudfish and longfin eels are classified at an At Risk – Declining species (Goodman *et al*. 2013).

Responding to the requirements of the Freshwater Fish Regulations and under the provisions of MPI permit NFT174 for fish translocations, the fish populations of the two largest industrial land parcels were removed prior to land development in 2011/2012. The fish were translocated to the Tanirau Wetland at Crawford Road. The species caught and transferred were black mudfish (12), longfin eel (2) and shortfin eel (16).

Anecdotal evidence from landowners indicates that fish species in the Crawford Road wetland area and stream include shortfin eel, longfin eel, giant kokopu (*Galaxias argentus*), banded kokopu, and koura (*Paranephrops planifrons*).

During the 2016 fish survey, a total of four fish species were identified (Table 6), including one exotic species (mosquitofish) and three native species (longfin eel, shortfin eel and banded kokopu). Four longfin eel were caught ranging from 500 to 1200mm, while three short fin eel were also captured ranging from 500 to 700mm. The banded kokopu consisted of one large adult approximately 150mm in size. A single shortfin eel, approximately 300mm in size, was captured during the single electric fishing run. Over 300 mosquito fish were caught.

Table 6: Fish Survey Results

Fish Species	Horotiu Rd
Longfin eel	4
Shortfin eel	3
Banded kokopu	1
Mosquitofish	>300
No. of species	4

The culverts at Ngaruawahia Road and Horotiu Road may present a barrier to fish passage, particularly non-climbing species. However, the permanent water flow over the willow root mass into the culvert is not expected to be a barrier for capable climbing species such as eels and kokopu. Black mudfish have also been found upstream so the culverts must present only a minor fish passage barrier. A complete waterway walkover was undertaken in 2012, excluding the inaccessible wetland area. Debris jams were not observed and would not normally be expected in a soft sediment waterway with little riparian cover or in the gully floor swamps.

The diversity and abundance of fish species is likely to increase substantially with distance downstream, as flows become perennial, channel morphology is less modified, habitat diversity increases, and riparian vegetation cover increases.

However, the intermittent drains and wetland areas throughout the catchment with peat-influenced groundwater baseflows will provide important habitat for threatened black mudfish. As discussed in Section 5.5 below, it is likely that small relict populations of the non-migratory species is present in suitable habitats with population size and distribution varying with water levels allowing eel access as occurs in similar locations east of the Waikato River. The relative habitat value of each intermittent drain is likely to be adversely affected by Drainage Board management activities such as spraying and excavation.

4.6 Erosion and Scour

Based on the 2012 walkover, upper catchment drains between Rotokauri Structure Plan Area and Te Kowhai/Koura Drives are small headwater waterways that are receive baseflows predominantly from groundwater rather than overland flow due to flat topography. Downstream of Te Kowhai/Koura Drives, the drains are substantially deeper and wider but baseflows are likewise groundwater-fed and surface drainage is minimal. As a result, fluvial erosion and scour are rare in the drains and bank instability tends to result from non-fluvial factors such as over steep banks (resulting from excavation) and vegetation removal (from spraying). This was confirmed by geotechnical investigation[14] into drain bank instability which concluded the most likely mechanism is bank vegetation removal from weak soil strata. Drain bank instability is localised and limited. Two notable locations of bank instability are at the confluence of the two upper catchment drain networks immediately downstream of Koura Drive and at the farm culvert sampling location, both present prior to the Rotokauri industrial site development.

In the modified stream reach upstream of Horotiu Road the channel is deeply incised with very steep banks and channel morphology indicates the bed is eroding. This reach has extensive bank instability with erosion and scour resulting in undercutting and bank failure ranging from small slumps to severe mass bank failure. This is principally in the channelised stream reach and appears to be the natural fluvial process of re-establishing a meandering flow path. In some areas, large scale bank failure is associated with large springs emanating near the bank toe.

Where rock riprap has been deposited to stabilise bank failure, underlying sediments have collapsed further causing lobes of sediment and rock within the channel diverting flows and causing scour upstream, opposite, and downstream of the lobes.

Most stream reaches are fenced to exclude stock but some fence and gate placement may be contributing to instability as a result of livestock pressure. As noted in Section 4.1.4, some stream reach were unfenced at the 2012 assessment with extensive erosion from livestock access but this is likely to have ceased after fencing. As for the drain reaches, the bank instability described above was present pre-development.

Downstream of Horotiu Road in the reach upstream of the wetland, the stream has a flatter gradient, is notably less incised and more connected with the adjacent floodplain. Erosion, scour and bank instability are rare. Likewise within the observable wetland channels, erosion and scour are likely to be associated only with discrete drain discharge points.

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[14] Coffey Geotechnics Ltd, 2012. Memorandum: Phase 1 - Drain Erosion Qualitative Assessment in Relation to the Proposed Rotokauri Industrial Development, Hamilton, Waikato

5.0 Discussion

5.1 Water Quality

Small headwater tributaries are vulnerable to effects from land use change because new stormwater discharges can make up a large proportion of post-development flows and therefore have a disproportionately large effect on downstream water quality. Although the proportion of existing and proposed industrial/employment zone land and roading in the Mangaheka Stream catchment is small, stormwater management based on TP10 design parameters (see Sections 1.2 and 1.3) could have effects on water quality downstream due to the small channel size and flow volume at the discharge points in spite of the existing poor water quality.

The Mangaheka Stream has water quality and water chemistry that is very similar to other Hamilton waterways. The stream receives ongoing inputs of suspended sediment, turbidity, nutrients, metals, and faecal pathogens although most metals and phosphorus have limited bioavailability, and even dissolved copper and zinc concentrations are below ANZECC thresholds.

However, an analysis of the water quality of Hamilton's rural, semi-urban, and urban waterways shows that although total contaminant loads may increase following urbanisation, contaminant concentrations can be expected to remain similar to pre-development. This is likely to be a result of pre-development stream baseflows sourced from shallow groundwater draining soils of historic wetlands which release continuously elevated metals loads. Analysis indicates that regardless of the proportion of urbanised catchment, concentrations of stormwater metals (copper, lead, zinc) do not change substantially even in catchments with large industrial catchments such as Waitawhiriwhiri Stream. Some metals are uniformly high throughout the area (aluminium, iron, zinc). However, for modern industrial areas, source control is appropriate for stormwater from high intensity industrial sites and land uses (e.g. high traffic load intersections and roundabouts, industrial sites, etc.) to prevent acute contaminant effects.

Provided that existing and proposed wetlands and detention basins maintain contaminant concentrations below ANZECC thresholds, the most important water quality issue associated with the upper catchment drains is elevated temperature and turbidity. Large open water areas and unplanted or sparsely planted stormwater swales are known to impacts water quality by raising temperature, reducing dissolved oxygen, and causing reduced water clarity. These conditions are likely to be adversely affecting the diversity and distribution of indigenous aquatic organisms in downstream habitats, when water flow in the upper catchment is occurring.

The faecal pathogen load is high (but about average compared to other catchments) which makes the water unsuitable for human contact or livestock consumption throughout the catchment. The high faecal pathogen load may present a public health risk for anyone in contact with the water or for fish and watercress consumption (Edmonds 2001). These activities are most likely in the lower catchment at the marae on the downstream end of the wetland. Water quality testing has not been carried out at this location.

On balance, the water quality and water chemistry of the Mangaheka Stream catchment is considered to be moderate to poor, but similar to most Hamilton waterways.

Based on the CLA (see Section 4.2.3), stormwater from urbanisation within the HCC boundary and roading is [likely/unlikely] to substantively change either contaminant yields or concentrations discharged downstream [CONFIRM].

There is a significant risk of effects from thermal pollution on the modified stream and drains that provide mudfish habitat, particularly after summer rainfall when drains are flowing and particularly if ponds are used as attenuation devices rather than planted wetlands or swales. On that basis, stormwater devices throughout the catchment must use planted swales and wetlands with >80% cover to maintain cool stormwater discharge temperatures.

5.2 Water Quantity

Based on the pre-development topography and soils of the upper catchment, and the location and flow direction of surface drains, when flowing, the drains provide groundwater-sourced base flows to the stream that it would not naturally have received. The peat wetlands are likely to have been self-contained systems with no outlet fed by local shallow groundwater systems, although deeper groundwater flow is likely to have been generally north-northwest. Increased impervious surfaces throughout the industrial/employment area combined with removal of the remaining drains to facilitate development will increase the volume of water discharging downstream, but may decrease the baseflows at low flows because water is being held in detention basins.

The stream has ecological significance as habitat for a range of threatened species in the middle and downstream catchments. The upper catchment is habitat for longfin eel and black mudfish. Eel and black mudfish populations are known to fluctuate in relation to one another based on the complex interplay between rainfall, baseflows, and fish passage. Where rainfall maintains baseflows, eel populations will enter a drain network and reduce mudfish populations through predation. When drains dry up regularly, eel populations migrate downstream or survive only in pool refugia, and mudfish populations can remain viable in the intermittently dry drain habitat where eel predation is limited or absent.

The upper catchment drains, including those within Hamilton City boundaries, are known to provide habitat for black mudfish and longfin eels, and are therefore considered to have ecological significance providing habitat for these threatened species. Provided that the post-development stormwater devices continue to discharge intermittently into the existing drain network and include surface swales and detention basins to maximise infiltration, then the hydrology of the drain network can be expected to remain approximately similar to pre-development.

5.3 Sediment Quality

Benthic fauna are likely to be limited to those species capable of withstanding periodic smothering from suspended sediment loads, intermittent flow, and high temperatures. Sediment contaminants are likely to have less important effects on benthic fauna diversity in the Mangaheka Stream than factors such as hydrology, suspended sediment inputs, benthic habitat quality, water temperature, sediment oxygen profile, and presence of aquatic macrophytes.

Overall, sediment quality is typical of agricultural watercourses with all metals detected but no notable issues.

5.4 Aquatic Macroinvertebrates

The MCI /SQMCI scores are consistent with those measured in similar open rural drain networks with intermittent water flow, groundwater-derived base flows, low aquatic macrophyte and riparian vegetation cover, poor bank stability, and water with elevated sediment, nutrient and metal concentrations. This reflects the catchment's rural and rural-residential land use and long term land drainage.

On balance, no change in the MCI/SQMCI scores can be expected as a result of completion of the industrial/employment areas development because macroinvertebrate communities are already comprised of very hardy and pollution tolerant species. The proportion of the total stream catchment being urbanised is small, and given the stormwater treatment proposed, effects on water quality and quantity are likely to be relatively small such that the aquatic macroinvertebrate community composition in the downstream environment is likely to remain unchanged.

The aquatic macroinvertebrate community diversity on the Mangaheka Stream could be improved with riparian vegetation replanting around the drain networks, as described in the Mangaheka Restoration Vision. This would provide channel shade, reduced temperature and increased organic material.

5.5 Fish

The factors to consider when assessing the fish diversity associated with rural waterways include aquatic and riparian habitat quality, water quality, community composition, and the presence of significant barriers to fish passage. Bearing in mind the relative lack of fish survey records for the large Tanirau Wetland area, actual fish diversity is likely to be greater than recorded fish diversity, with bully species absent from the records but likely to be present. However, in the remainder of the waterway, species diversity close to what would be expected in natural conditions for this type of intermittent lowland Waikato stream with peat influences. Although inanga (*Galaxias maculatus*) and smelt (*Retropinna retropinna*) would normally be expected, these species are unlikely to naturally occupy the willow wetland reaches, precluding movement upstream into the middle and upper reaches.

Of importance to this assessment, the intermittent upper catchment would naturally be expected to provide habitat only for eels and black mudfish which have been observed either in fish surveys or translocations. Provided that stormwater treatment maintains dissolved contaminant concentrations below ANZECC thresholds and the design assumptions set out in Sections 1.2 and 1.3 are implemented, continued development of the Rotokauri Structure Plan industrial and employment areas is unlikely to affect fish diversity.

Replanting riparian vegetation cover throughout the modified stream catchment may increase the viable habitat for species such as banded kokopu. giant kokopu, and bullies further upstream in the catchment, but their upstream extent will be limited to perennial reaches. Likewise, replanting riparian vegetation in the drain networks would improve habitat for mudfish, eels and aquatic macroinvertebrates, while also improving bank armouring.

Given the species found upstream, the perched Horotiu Road culverts are not a significant fish passage barrier.

5.6 Erosion and Scour

Ongoing development of the industrial/employment areas will substantially increase impervious areas over part of the upper catchment, reducing infiltration to groundwater and increasing the volume and speed of surface runoff. This is mitigated by two existing stormwater detention basins designed to TP10 standards installed to attenuate peak flows and reduce discharge velocity to less than pre-development rates at the pre-existing drain network discharge points. [COMMENT ON ROAD DEVICE DESIGN] Development of additional industrial/employment areas is likely to have similar volume and peak flow attenuation requirements.

However, regardless of the degree of flow attenuation, increased imperviousness will result in larger stormwater volumes being discharged over longer durations based on the modelled pre-development and post-development runoff characteristics. Based on topography and existing waterway characteristics, particularly the pre-development erosion pattern, there is potential for additional flow volumes to cause bank instability in the drains immediately downstream of the discharge points, particularly non-vegetated drains with very steep banks. Additional volume may also exacerbate existing erosion at the Koura Drive confluence.

Increased erosion related to increased volume is less likely in shallow drains with battered banks and riparian vegetation cover and/or aquatic macrophytes upstream of Te Kowhai Road. Most erosion effects would be expected to be experienced in the first several hundred meters downstream of discharge points, but may extend further downstream over time as channel morphology changes in response to the new flow regime. The effect of increased erosion on the drains relates principally to bank stability, rather than the riparian or aquatic environment which is artificial and has low ecological values.

Based on visual assessment of the waterways, there is unlikely to be a measurable change in the existing bank instability in the modified stream reach upstream of Horotiu Road.

Erosion and scour effects can be prevented by:

- Fencing the waterways to prevent stock access.
- Battering back banks to reduce instability.
- Planting indigenous riparian plants specifically chosen to improve bank stability and protect the channel bed (see Plant Selection Tool for Waikato Waterways and Mangaheka Restoration Vision).

However, given the complexities of the downstream waterway ownership and management, and the poor quality artificial habitat, it may be more appropriate to monitor for changes in erosion and bank stability and retrofit solutions if effects are detected.

6.0 Risks and Sensitivities

On the basis of Sections 2.0 – 5.0 above, there are a number of risks associated with stormwater management in the Mangaheka Stream catchment as a result of industrial/employment zone land development, based on the particular sensitivities identified.

The upper catchment waterways (drains) are small, artificial, and have poor habitat values. Water quality is modified by land drainage and agricultural land use, and affected by intermittent flow and lack of riparian or instream vegetation. Water quality is likely to experience spikes of contaminants (sediment, metals, and nutrients) after rainfall, particularly when drains have previously been dry. The aquatic macroinvertebrate community reflects the combination of poor habitat values and poor water quality. The contaminant load assessment indicates that stormwater contaminant effects are [???] based on assumed means of compliance installation and performance [CONFIRM]. Thermal pollution is a risk to downstream waterways if swales and detention basins are not planted or plant cover is low with potential for significant effects on threatened black mudfish.

In the drains with steep banks and little riparian vegetation, there is a risk that increased stormwater discharge volumes will increase bank instability.

Sediment quality is moderate to good. Based on conventional TP10 stormwater design, this is likely to be unchanged by urbanisation or roading.

Fish diversity in the catchment is close to what would be expected naturally and the identified fish passage obstacles present only a minor barrier. However, lack of riparian cover and waterway habitat values in the upstream drains limit the use of the habitat by fish, provide poor conditions for the aquatic macroinvertebrate community, and impact water quality.

The existing farm drains in the undeveloped portions of the Rotokauri Structure Plan industrial/employment areas are likely habitat for threatened fish species (longfin eel and black mudfish). The presence of these threatened species means the drains have ecological significance under the provisions of the RPS, and their removal will require mitigation and offset measures to replace the habitats.

Effects of stormwater discharges, bank instability, and drain removal/modification are not expected to be measurable in the modified stream reach or the Tanirau Wetland.

Table 7 summarises the assessment of risks and sensitivities of the upper drain catchment associated with stormwater discharges into the Mangaheka Stream and industrial/employment zone land development.

Table 7: Mangaheka Stream upper catchment risks & sensitivities

Environmental value	Existing state or values	Potential effects of future stormwater management?	Proposed Objective
Riparian habitat	Variable, but typically low intrinsic value in stream and drain reaches.	Yes	<u>Explanation:</u> The very limited existing riparian values are unlikely to be changed by future stormwater discharges. Low riparian vegetation cover affects bank stability and water quality. Increased stormwater volumes may cause bank instability in steep unvegetated drains. <u>Objective:</u> Riparian vegetation density and cover is maintained and/or enhanced downstream of stormwater discharge points on the Mangaheka Stream to maintain habitat stability and water quality. <u>Recommendations:</u> To avoid bank instability, dense riparian vegetation cover must be maintained where present. Where riparian vegetation replanting is proposed to avoid downstream bank instability, it must consist of indigenous eco-sourced plant species appropriate to the lowland Waikato location in accordance with the Mangaheka Restoration Vision.
Aquatic habitat	Moderate, ecological significance	Yes	<u>Explanation:</u> Site development in the undeveloped industrial/employment areas will remove riparian vegetation and waterways that are potential habitat of threatened fish species (longfin eel and black mudfish). <u>Objective:</u> Meet the requirements of the RPS provisions for avoiding adverse effects on habitats of significance indigenous fauna. <u>Recommendations:</u> Work with WRC and landowners of undeveloped land in the Rotokauri Structure Plan industrial/employment areas to identify appropriate methods of providing longfin eel and black mudfish habitat either within the site or in alternative offsite habitats.
Water quality	Poor	Yes	<u>Explanation:</u> There is potential for stormwater discharges to impact water quality if inappropriate devices are installed or if installed devices do not achieve design standards for treatment.

Environmental value	Existing state or values	Potential effects of future stormwater management?	Proposed Objective
			<u>Objectives:</u> Mass loads or concentrations of stormwater contaminants in the Mangaheka Stream are not increased above ANZECC thresholds as a result of industrial/employment zone land development. Temperature in the Mangaheka Stream is not increased above 23°C in summer and 14°C in winter downstream of all stormwater discharge points when flow is occurring. <u>Recommendations:</u> To avoid potential thermal pollution, stormwater treatment devices must avoid open water ponds and achieve wetland/riparian plant cover >80% to maintain cool downstream temperatures. Undertake monitoring (Section 10) to confirm device performance, and detect changes in contaminant profile and temperature over time. Work with WRC and downstream landowners with unplanted drains to establish dense riparian vegetation consisting of indigenous eco-sourced plant species appropriate to the lowland Waikato location in accordance with the Mangaheka Restoration Vision.
Water quantity	Intermittent	Yes	<u>Explanation:</u> Intermittent flows are important to maintaining habitat for threatened black mudfish. Changing drain hydrology to perennial flow should be avoided. <u>Objective:</u> Discharges into the Mangaheka Stream from the Rotokauri Structure Plan industrial/employment areas continue to provide intermittent flows. <u>Recommendation:</u> To avoid increasing drain base flows, stormwater devices are not required to discharge continuously to the Mangaheka Stream receiving waters.
Sediment quality	Moderate - Low	No	<u>Explanation:</u> On the basis of TP10 minimum design standards for treatment and existing sediment quality, there is unlikely to be a notable change in sediment quality as a result of stormwater discharges into Mangaheka Stream receiving waters.

Environmental value	Existing state or values	Potential effects of future stormwater management?	Proposed Objective
Aquatic macroinvertebrates	Low	[???]	Explanation: On the basis of the CLA, stormwater discharges are [???] reduce biodiversity as a result of increased stormwater contaminant yields or concentrations [CONFIRM]. See objective in Water Quality above and Erosion & Scour section below.
Indigenous fish	Moderate, threatened species present	Yes	Explanation: Site development in the undeveloped industrial/employment areas will remove riparian vegetation and waterways that are potential habitat of threatened fish species (longfin eel and black mudfish). See objective in Water Quality above and Erosion & Scour section below.
Erosion & Scour	Stable in drain reaches, unstable in modified stream reaches.	Yes	Explanation: There is potential for increased erosion resulting from increased stormwater volume in drain reaches downstream of discharge point, particularly where banks are steep and unvegetated. If monitoring determines that drain bank instability downstream of discharge points is increasing, riparian planting is the most appropriate method of increasing armouring of bank sediments while enhancing water and habitat quality in an ecologically significant habitat. Bank battering and engineered solutions may be required in specific locations. Objective: Bank instability of Mangaheka Stream drains downstream of stormwater discharge points is not increased. Recommendations: Undertake monitoring (Section 10) of drains downstream of the discharge points to detect changes in bank instability over time. On drain reaches downstream of stormwater discharge points where an increase in bank instability is measured and confirmed as a result of stormwater discharges, drains must be managed to improve bank stability in conjunction with the landowner and WRC using a combination of methods appropriate to the specific location such as: Batter back over-steep drain banks and fence drains to exclude stock at less than 1m from the bank crest. Plant indigenous eco-sourced riparian and/or wetland/aquatic plant species with rhizome root systems appropriate to the lowland Waikato location in accordance with the Mangaheka Restoration Vision.

7.0 Monitoring Programme

The purpose of monitoring to support an ICMP is to:

- Ensure that the assumptions on which objectives were based remain valid, and
- Determine whether implemented measures are effective at achieving the objectives.

The following monitoring parameters are recommended to ensure that discharge quality is as expected and that bank instability does not increase post-development.

1. Downstream of stormwater discharge points for the Rotokauri Structure Plan industrial/employment areas and Waikato Expressway/Koura Drive, within the zone of reasonable mixing, undertake water quality monitoring consistent with the HCC Comprehensive Stormwater Discharge Consent methodology for the analytes set out in Table 2, plus temperature and dissolved oxygen. The purpose of the analysis is to monitor discharge quality to ensure compliance with the Discharge Consent. The contaminant concentrations should be compared against USEPA water quality criteria.
2. At the Te Kowhai Road, Murray farm, and Horotiu Road culverts, undertake water quality monitoring consistent with the HCC Comprehensive Stormwater Discharge Consent methodology for the analytes set out in Table 2, plus temperature and dissolved oxygen. The purpose of the analysis is to monitor post-development changes in baseline stormwater contaminant concentrations and water quality parameters to confirm the contaminant load assessment. The contaminant concentrations should be compared against ANZECC guidelines.
3. During storm flows, take an annual grab sample of stormwater at the inlets and outlets of the Rotokauri Structure Plan industrial/employment areas and Waikato Expressway/Koura Drive treatment devices to confirm the TP10 design (or alternative consented design) contaminant removal efficiency is being achieved.
4. Between stormwater discharge points and the Murray farm culvert, undertake a bi-annual drain walkover to observe and measure bank instability extent and severity. Compare the results with the baseline erosion survey information to determine whether observable changes in erosion, scour, and bank instability are occurring.

8.0 Conclusion

Urbanisation will occur within the Mangaheka Stream catchment will continue to occur within the Rotokauri Structure Plan area, which comprises a small proportion of the stream catchment. As a result, increased stormwater volumes will be discharged into the Mangaheka Stream's headwater drains at or near their upstream extent.

The receiving environments are small tributary drains with poor riparian and aquatic habitat, and poor water quality. The upper catchment drains support a highly pollution tolerant aquatic macroinvertebrate community and a naturally depauperate fish community affected by intermittent flow and poor habitat quality.

Based on the existing water quality, there is a risk that urbanisation has and will continue to decrease water quality due to thermal pollution, even with stormwater treatment devices designed to TP10 standards. Stormwater treatment devices need to maintain existing water chemistry and quality, and densely planted devices are the most appropriate method of achieving this.

Because the drains and downstream modified stream are small watercourses, they are vulnerable to effects from stormwater discharges which will form a disproportionately large part of the post-development flows. There is a risk that such discharges will have adverse effects on bank stability and erosion unless regular monitoring and preventative management is undertaken.

The Mangaheka Stream catchment upstream of Horotiu Road provides existing habitat for shortfin eels and banded kokopu, and threatened longfin eels and black mudfish, conferring ecological significance on the waterway. Eels and mudfish have been found in the upstream drains. Fish habitat and fish passage in upstream habitats must be maintained in proposed road corridors and land development areas, or replaced with equivalent or enhanced habitats.

To reduce potential for stormwater management resulting from urbanisation to have adverse effects, objectives are provided for each of the main risks. On the basis of the information currently available regarding the ecological values of the Mangaheka Stream and the proposed urbanisation for industrial and employment zones, actions have been recommended to prevent or mitigate effects on ecological values. Monitoring is recommended to ensure that the recommended actions have achieved the objectives.

9.0 References

ANZECC. 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Auckland Regional Council 2003. Stormwater Management Devices: Design guidelines manual. Technical publication 10 (TP10).

Brough, A.; Brunton, R.; England, M.; Eastman, R. 2012. Stormwater Quality – An analysis of runoff from modern subdivisions and the implications for stormwater treatment. Proceedings: Water New Zealand Stormwater Conference 2012.

Clarkson, B.D.; Clarkson, B.R.; Downs, T.M. 2007. Indigenous Vegetation Types of Hamilton Ecological District. CBER Contract Report 58. University of Waikato.

Clarkson, B.D.; McQueen, J.C. 2004. *Ecological Restoration in Hamilton City, North Island, New Zealand.* Proceedings from the 16th International Conference, Society for Ecological Restoration, August 24-26 2004, Victoria, Canada.

Cornes, T.S.; Thomson, R.E.; Clarkson, B.D. 2012. *Key Ecological Sites of Hamilton City – Volume I*. CBER Contract Report 121 prepared for Hamilton City Council.

David, B.O. & Speirs, D.A. 2010. 10. Native fish. *In:* Collier, K.J.; Hamilton, D.P.; Vant, W.N.; Howard-Williams, C. (eds.). *The Waters of the Waikato: Ecology of New Zealand's Longest River.* Environment Waikato and the Centre for Biodiversity and Ecology Research, The University of Waikato.

Edmonds, C. 2001. Microbiological & Heavy Metal Contamination of Watercress in the Wellington Region. Unpublished thesis, Victoria University of Wellington.

Goodman, JM; Dunn, NR; Ravenscroft, PJ; Allibone, RM; Boubee, JAT; David, BO; Griffiths, M; Ling, N; Hitchmough, RA; & Rolfe, JR. 2013. Conservation status of New Zealand freshwater fish, 2013. Department of Conservation New Zealand Threat Classification Series 7.

McDowall, R.M. 2000. *The Reed Field Guide to New Zealand Freshwater Fishes*. Reed Books, Auckland.

Ministry for the Environment 1992. Water Quality Guidelines No. 1: Guidelines for the Control of Undesirable Biological Growths in Water.

Ministry for the Environment 2001. *Protocols for sampling macroinvertebrates in wadeable streams*. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103.

Ministry for the Environment 2003. *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas*. Ministry for the Environment, Wellington.

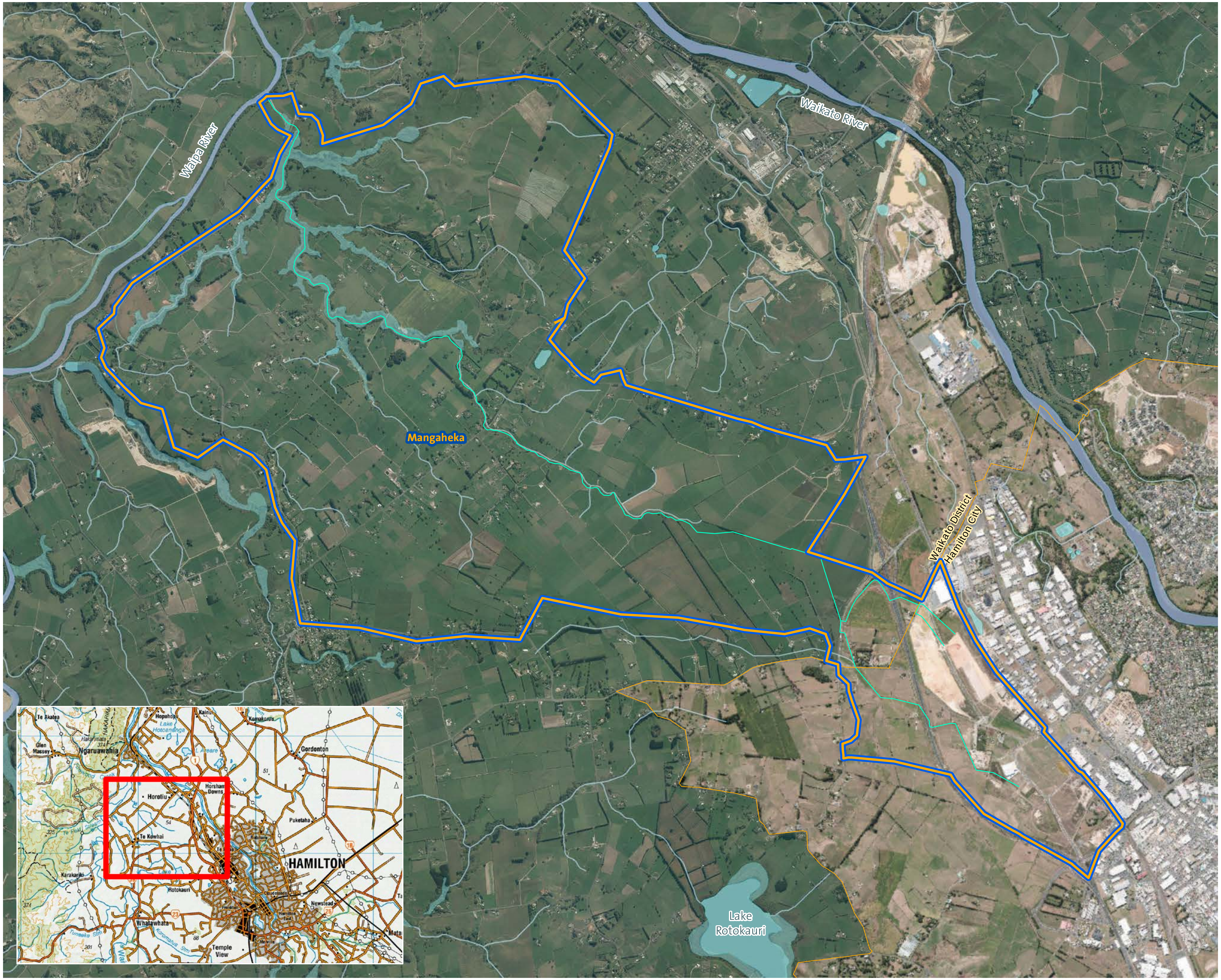
Nicholls, J. 2002. 3. History of the vegetation. *In:* Clarkson, B.; Merrett, M.; Downs, D. (compilers). Botany of the Waikato. Waikato Botanical Society Inc., Hamilton.

NIWA 2001. Hamilton City Stormwater: assessment of contaminant loads and impacts on the Waikato River. NIWA Client Report: HCC00210.

Speirs, D. 2001. The Diversity and Distribution of Freshwater Fish and their Habitat in the Major Rivers of the Waikato Region. Environment Waikato Technical Report 2001/11

Stark, J.D. and J.R. Maxted 2007. A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research*. Vol. 41: 43-61.

Appendix 1 – Figures



File Ref: T15161_Figure1_CatchmentBoundary.mxd

Legend

Topographic Catchment Boundary

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Sources: Aerial photography sourced from Waikato Regional Council (WRAPS 2012). Topographic information sourced from Land Information New Zealand.

Sub-catchment data sourced from Lysaght Consultants Ltd, as per plan titled "2012-06-27 - 112196 - BML - Catchment Boundaries.dwg"

Projection: NZGD 2000 New Zealand Transverse Mercator

MANGAHEKA ICMP

Figure 1
Catchment Boundaries

Date: 23 June 2016
Revision: 0

Plan Prepared for the Hamilton City Council by Boffa Miskell Limited
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Drawn: JWa *Checked:* LSa

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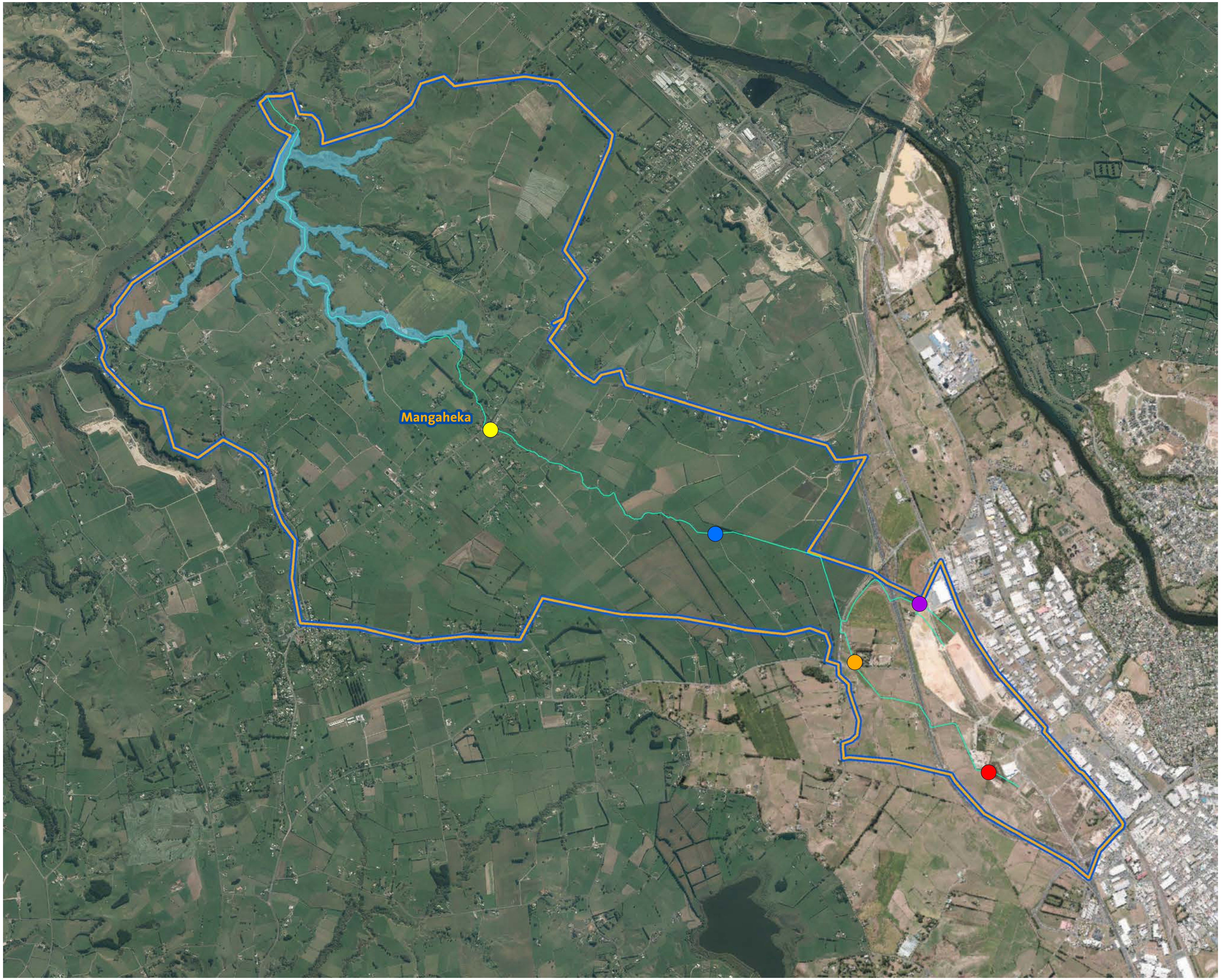
File Ref: T15161_Figure2_SampleSites.mxd



Legend

2016 Sample Site

- Horotiu Road

2012 Sample Sites

- HJV Boundary
- Ruffell Road
- Te Kowhai Road Culvert
- The Farm Culvert
- Wetland
- Waterway
- Topographic Catchment Boundary

0 1 km

1:30,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

MANGAHEKA ICMP

Figure 2
Sample Sites

Date: 23 June 2016
Revision: 0

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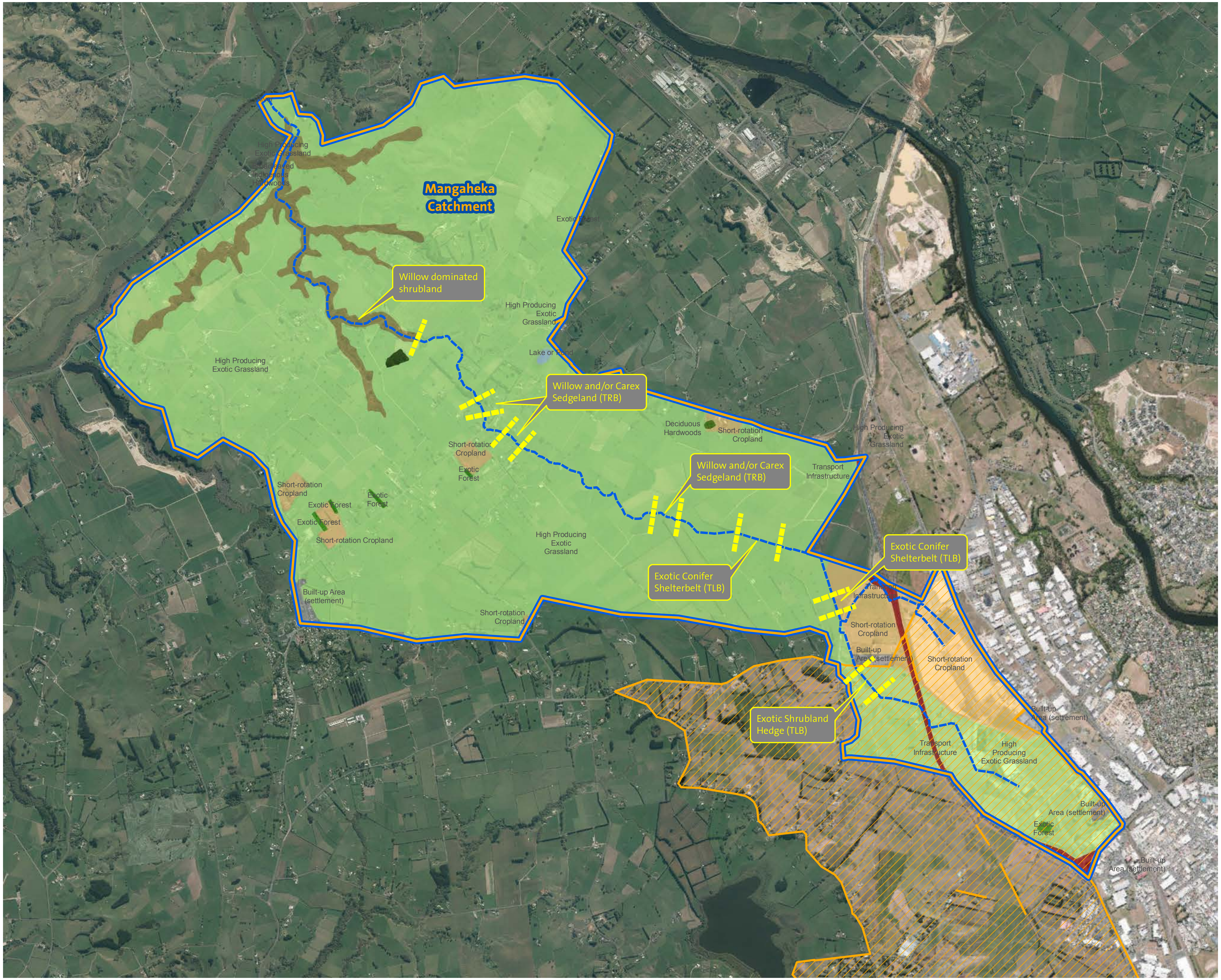

Legend

- Topographic Catchment Boundary
- Stormwater Centreline
- Structure Plan Area
- Built-up Area (settlement)
- Transport Infrastructure
- Lake or Pond
- River
- Short-rotation Cropland
- High Producing Exotic Grassland
- Low Producing Grassland
- Broadleaved Indigenous Hardwoods
- Deciduous Hardwoods
- Indigenous Forest
- Exotic Forest

0 — 1.2 km

1:30,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, Hamilton City Council.

Projection: NZGD 2000 New Zealand Transverse Mercator

MANGAHEKA ICMP

Figure 3
Riparian Vegetation

Date: 23 June 2016
Revision: 0

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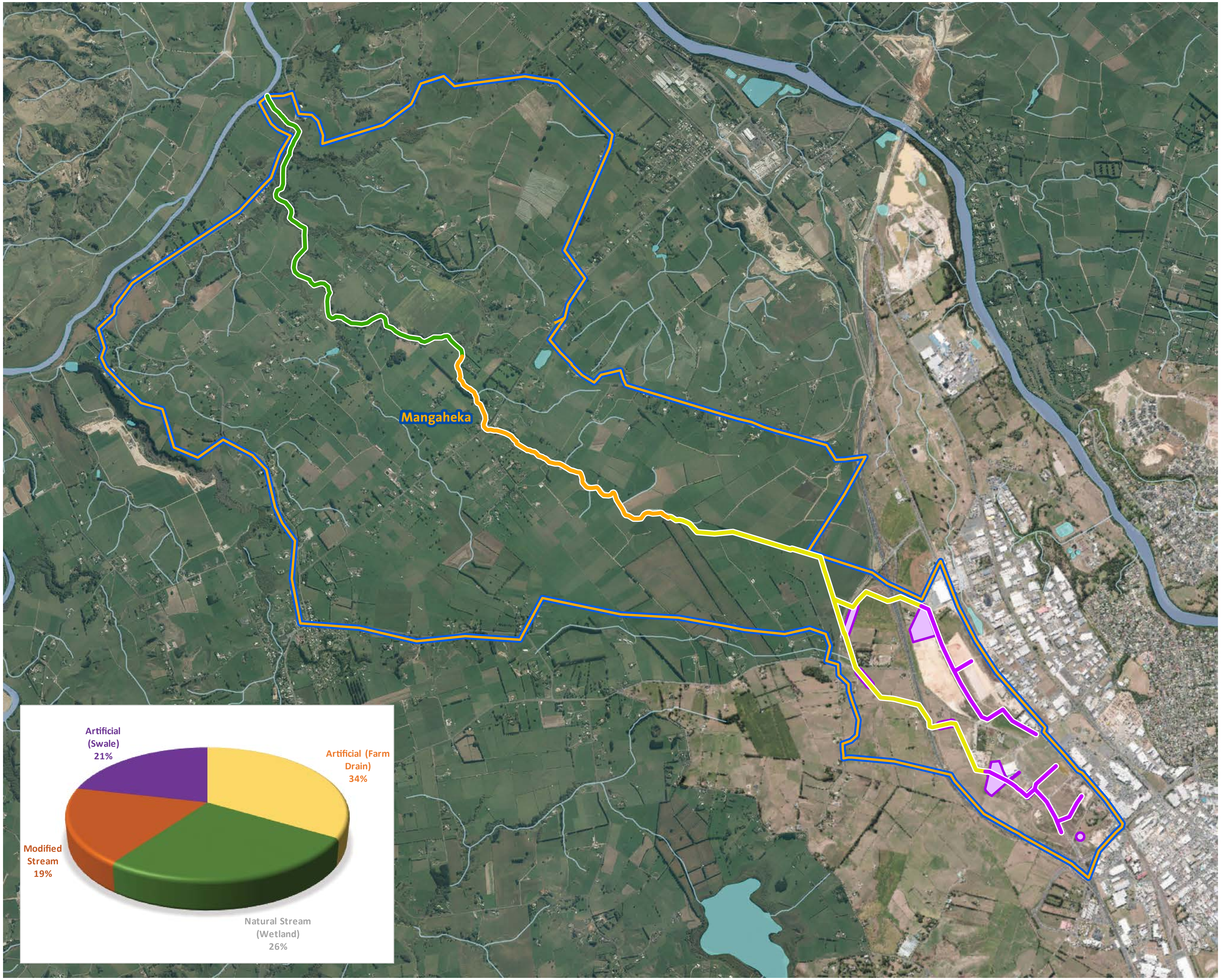

Legend

Stormwater Centreline

- Artificial (Farm Drain)
- Artificial (Swale)
- Modified Stream
- Natural Stream (Wetland)
- Topographic Catchment Boundary
- Artificial Ponds
- River Centreline - NZTopo50
- Lake - NZTopo50
- Pond - NZTopo50
- River - NZTopo50

0 — 1.2 km

1:30,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

MANGAHEKA ICMP

Figure 4
Hydrography

Date: 23 June 2016
Revision: 0

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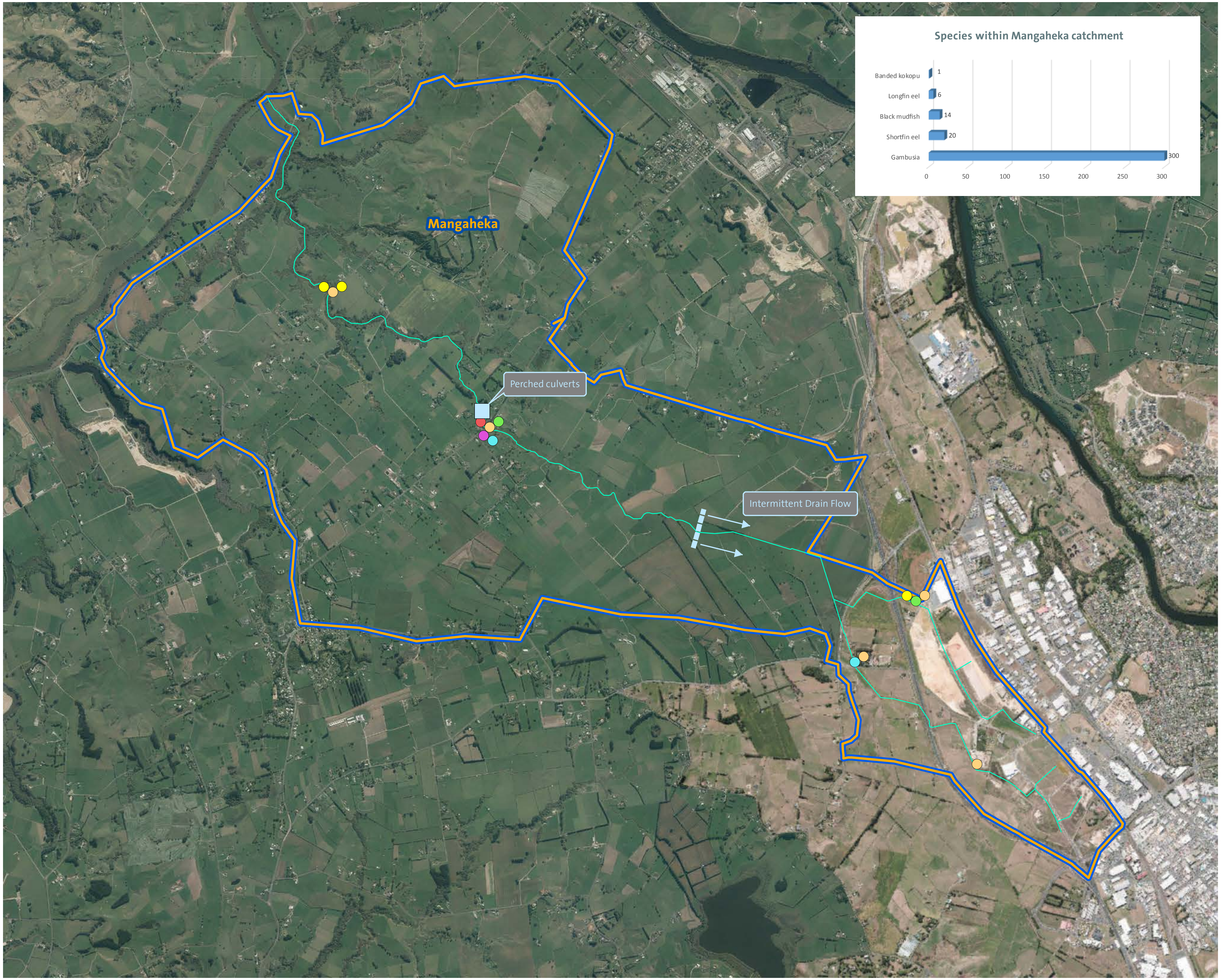
File Ref: T15161_Figure5_Fish.mxd



Legend

Freshwater Fish Database records

- Shortfin eel
- Longfin eel
- Banded kokopu
- Gambusia
- Black mudfish
- No species recorded

Potential and actual fish passage barrier

0 1.2 km

1:30,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

MANGAHEKA ICMP

Figure 5
Freshwater Fish

Date: 24 June 2016
Revision: 0

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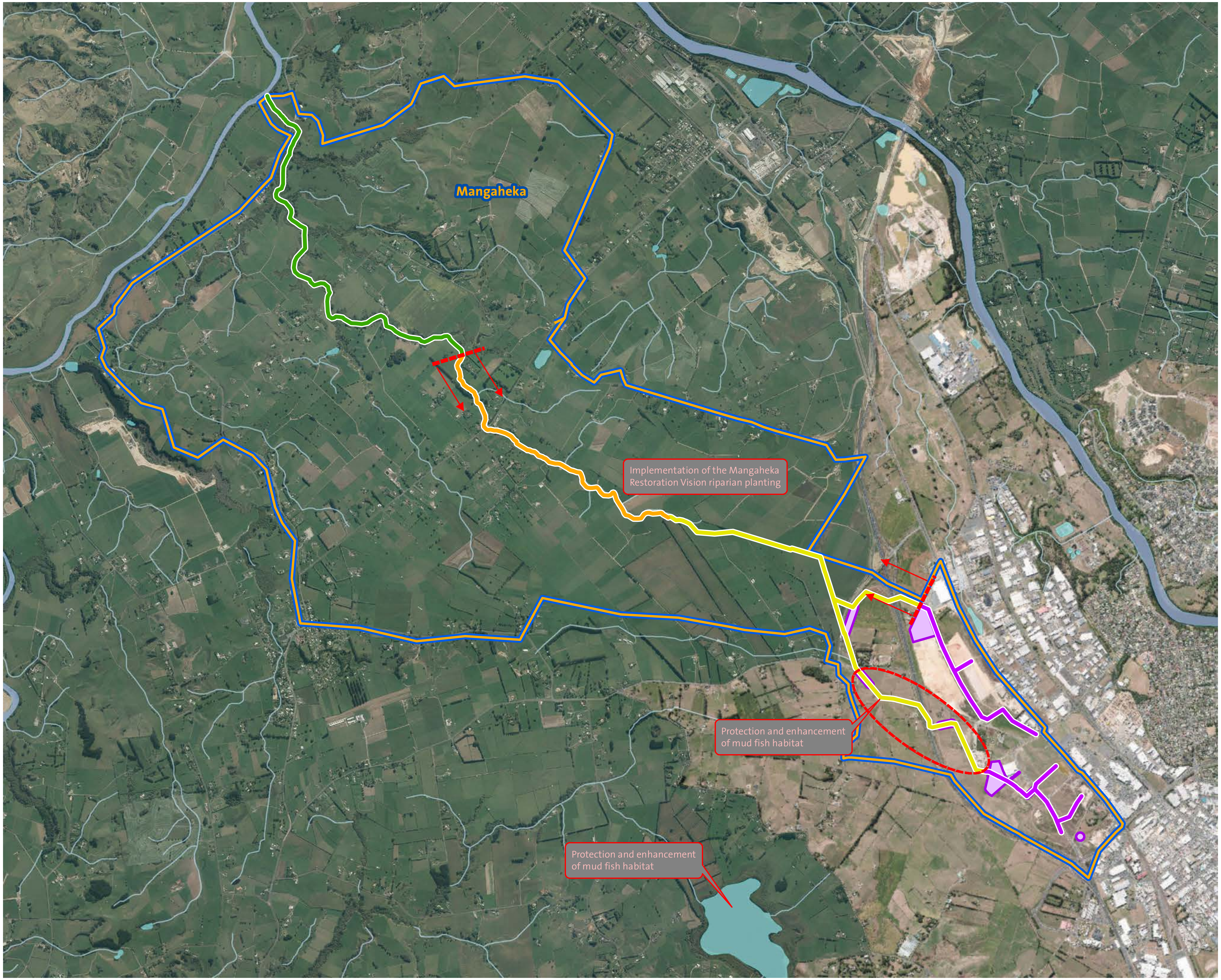

File Ref: T15161_Figure6_EcoEnhanceOps.mxd

Legend

Stormwater Centreline

- Artificial (Farm Drain)
- Artificial (Swale)
- Modified Stream
- Natural Stream (Wetland)
- Topographic Catchment Boundary
- Artificial Ponds
- River Centreline - NZTopo50
- Lake - NZTopo50
- Pond - NZTopo50
- River - NZTopo50

0 1.2 km

1:30,000 @ A3

Sources: Waikato Regional Council (WRAPS 2012), Land Information New Zealand, AECOM Limited.

Projection: NZGD 2000 New Zealand Transverse Mercator

MANGAHEKA ICMP

Figure 6

Ecological Enhancement Opportunities

Date: 23 June 2016
Revision: 0

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Appendix 2 – Water and Sediment Analysis Reports

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ANALYSIS REPORT

SPv1

Client:	Boffa Miskell Limited	**Lab No:**	1018512
Contact:	S Bathgate	**Date Registered:**	20-Jun-2012
	C/- Boffa Miskell Limited	**Date Reported:**	02-Jul-2012
	PO Box 13373	**Quote No:**	49903
	TAURANGA 3141	**Order No:**	
		Client Reference:	SW and Fresh Water Sedime
		Submitted By:	S Bathgate

Sample Type: Sediment

Sample Name:		Ruffell Rd 1 20-Jun-2012 10:50 am	Te Kowhai Rd 1 20-Jun-2012 11:20 am	Murray Culvert 1 20-Jun-2012 12:00 pm	Clarke Boundary 1 20-Jun-2012 1:00 pm	
Lab Number:		1018512.1	1018512.2	1018512.3	1018512.4	
Individual Tests						
Total Recoverable Iron	mg/kg dry wt	6,100	37,000	16,300	12,300	-
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	5	20	12	13	-
Total Recoverable Cadmium	mg/kg dry wt	< 0.10	1.05	0.23	0.38	-
Total Recoverable Chromium	mg/kg dry wt	4	10	6	7	-
Total Recoverable Copper	mg/kg dry wt	4	51	9	26	-
Total Recoverable Lead	mg/kg dry wt	4.9	15.7	12.3	14.1	-
Total Recoverable Nickel	mg/kg dry wt	2	7	3	3	-
Total Recoverable Zinc	mg/kg dry wt	28	162	54	33	-

Sample Type: Aqueous

Sample Name:		Ruffell Rd 1 20-Jun-2012 10:50 am	Te Kowhai Rd 1 20-Jun-2012 11:20 am	Murray Culvert 1 20-Jun-2012 12:00 pm	Clarke Boundary 1 20-Jun-2012 1:00 pm	
Lab Number:		1018512.5	1018512.6	1018512.7	1018512.8	
Individual Tests						
Turbidity	NTU	18.2	18.0	23	12.9	-
pH	pH Units	6.5	6.4	6.4	5.8	-
Total Suspended Solids	g/m^3	10	13	13	6	-
Total Copper	g/m^3	0.0022	0.0028	0.0026	0.0025	-
Total Iron	g/m^3	1.04	1.61	1.87	2.1	-
Total Lead	g/m^3	0.00032	< 0.00011	0.00019	0.00024	-
Total Zinc	g/m^3	0.069	0.023	0.033	0.0175	-
Total Nitrogen	g/m^3	4.2	2.5	4.6	1.66	-
Nitrate-N + Nitrite-N	g/m^3	3.1	1.39	3.4	0.52	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	1.08	1.12	1.21	1.14	-
Dissolved Reactive Phosphorus	g/m^3	0.005	0.012	0.007	0.005	-
Total Phosphorus	g/m^3	0.056	0.106	0.077	0.058	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	g O_2/m^3	< 2	< 2	< 2	< 2	-
Escherichia coli	cfu / 100mL	430	700 #1	900 #1	1,100 #1	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	< 0.15	< 0.15	< 0.10	-
C10 - C14	g/m^3	< 0.2	< 0.4	< 0.4	< 0.2	-
C15 - C36	g/m^3	< 0.4	< 0.8	< 0.8	< 0.4	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	< 1.4	< 1.4	< 0.7	-

Analyst's Comments

Please interpret these microbiological results with caution as the sample temperature was >10 °C on receipt in the lab. Samples are required to be less than 10 °C (but not frozen).

#1 Statistically estimated count based on the theoretical countable range for the stated method.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Samples
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-4
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	-	1-4
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-4
Total Recoverable Iron	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-4

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Samples
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	5-8
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	5-8
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 21st ed. 2005.	-	5-8
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	5-8
Total Phosphorus Digestion	Acid persulphate digestion.	-	5-8
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 21st ed. 2005.	0.05 NTU	5-8
pH	pH meter. APHA 4500-H^+ B 21st ed. 2005.	0.1 pH Units	5-8
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 21st ed. 2005.	3 g/m^3	5-8
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005 / US EPA 200.8.	0.00053 g/m^3	5-8
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.021 g/m^3	5-8
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005 / US EPA 200.8.	0.00011 g/m^3	5-8
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 21st ed. 2005 / US EPA 200.8.	0.0011 g/m^3	5-8
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N.	0.05 g/m^3	5-8
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (Modified) 21st ed. 2005.	0.002 g/m^3	5-8
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} C. (modified) 4500 NH_3 F (modified) 21st ed. 2005.	0.10 g/m^3	5-8
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005.	0.004 g/m^3	5-8
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005.	0.004 g/m^3	5-8
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 5210 B 21st ed. 2005.	2 g O_2/m^3	5-8
Escherichia coli	Membrane filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, MUG Confirmation. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 9222 G, 21st ed. 2005.	1 cfu / 100mL	5-8

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

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BETTER TESTING **BETTER RESULTS**

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ANALYSIS REPORT

Client:	Boffa Miskell Limited	**Lab No:**	1570413 SPv1
Contact:	L Saunders	**Date Registered:**	19-Apr-2016
	C/- Boffa Miskell Limited	**Date Reported:**	02-May-2016
	PO Box 13373	**Quote No:**	76181
	Tauranga 3141	**Order No:**	T15161
		Client Reference:	Mangaheka Stream
		Submitted By:	Kieran Miller

Sample Type: Sediment

Sample Name:		Mangaheka 1 (Sed) 19-Apr-2016 11:20 am				
Lab Number:		1570413.1				
Individual Tests						
Total Organic Carbon*	g/100g dry wt	0.70	-	-	-	-
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	8	-	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.16	-	-	-	-
Total Recoverable Chromium	mg/kg dry wt	3	-	-	-	-
Total Recoverable Copper	mg/kg dry wt	2	-	-	-	-
Total Recoverable Lead	mg/kg dry wt	3.2	-	-	-	-
Total Recoverable Nickel	mg/kg dry wt	< 2	-	-	-	-
Total Recoverable Zinc	mg/kg dry wt	34	-	-	-	-

Sample Type: Aqueous

Sample Name:		Mangaheka 1 (SW) 19-Apr-2016 11:20 am				
Lab Number:		1570413.2				
Individual Tests						
Turbidity	NTU	6.2	-	-	-	-
pH	pH Units	6.9	-	-	-	-
Total Suspended Solids	g/m^3	5	-	-	-	-
Dissolved Aluminium	g/m^3	0.010	-	-	-	-
Total Aluminium	g/m^3	0.022	-	-	-	-
Dissolved Iron	g/m^3	0.91	-	-	-	-
Total Iron	g/m^3	2.4	-	-	-	-
Total Nitrogen	g/m^3	0.44	-	-	-	-
Total Kjeldahl Nitrogen (TKN)	g/m^3	0.38	-	-	-	-
Total Phosphorus	g/m^3	0.035	-	-	-	-
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	$g\ O_2/m^3$	< 2	-	-	-	-
Faecal Coliforms	cfu / 100mL	410 [#1]	-	-	-	-
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Dissolved Arsenic	g/m^3	< 0.0010	-	-	-	-
Dissolved Cadmium	g/m^3	< 0.00005	-	-	-	-
Dissolved Chromium	g/m^3	< 0.0005	-	-	-	-
Dissolved Copper	g/m^3	< 0.0005	-	-	-	-
Dissolved Lead	g/m^3	< 0.00010	-	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	-	-	-	-
Dissolved Zinc	g/m^3	< 0.0010	-	-	-	-

Sample Type: Aqueous						
Sample Name:		Mangaheka 1 (SW) 19-Apr-2016 11:20 am				
Lab Number:		1570413.2				
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Arsenic	g/m³	< 0.0011	-	-	-	-
Total Cadmium	g/m³	< 0.000053	-	-	-	-
Total Chromium	g/m³	< 0.00053	-	-	-	-
Total Copper	g/m³	< 0.00053	-	-	-	-
Total Lead	g/m³	< 0.00011	-	-	-	-
Total Nickel	g/m³	< 0.00053	-	-	-	-
Total Zinc	g/m³	0.0012	-	-	-	-
Nutrient Profile						
Total Ammoniacal-N	g/m³	0.064	-	-	-	-
Nitrite-N	g/m³	0.004	-	-	-	-
Nitrate-N	g/m³	0.055	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.058	-	-	-	-
Dissolved Reactive Phosphorus	g/m³	0.005	-	-	-	-
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq						
Acenaphthene	g/m³	< 0.00010	-	-	-	-
Acenaphthylene	g/m³	< 0.00010	-	-	-	-
Anthracene	g/m³	< 0.00010	-	-	-	-
Benzo[a]anthracene	g/m³	< 0.00010	-	-	-	-
Benzo[a]pyrene (BAP)	g/m³	< 0.00010	-	-	-	-
Benzo[b]fluoranthene + Benzo[j] fluoranthene	g/m³	< 0.00010	-	-	-	-
Benzo[g,h,i]perylene	g/m³	< 0.00010	-	-	-	-
Benzo[k]fluoranthene	g/m³	< 0.00010	-	-	-	-
Chrysene	g/m³	< 0.00010	-	-	-	-
Dibenzo[a,h]anthracene	g/m³	< 0.00010	-	-	-	-
Fluoranthene	g/m³	< 0.00010	-	-	-	-
Fluorene	g/m³	< 0.0002	-	-	-	-
Indeno(1,2,3-c,d)pyrene	g/m³	< 0.00010	-	-	-	-
Naphthalene	g/m³	< 0.0005	-	-	-	-
Phenanthrene	g/m³	< 0.0004	-	-	-	-
Pyrene	g/m³	< 0.0002	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

Analyst's Comments

#1 Please interpret this result with caution as the sample was > 8 °C on receipt at the lab. The sample temperature is recommended by APHA to be less than 8 °C on receipt at the laboratory (but not frozen). However, it is acknowledged that samples that are transported quickly to the laboratory after sampling, may not have been cooled to this temperature.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	0.10 - 4 mg/kg dry wt	1
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Heavy metals, dissolved, trace As,Cd,Cr,Cu,Ni,Pb,Zn	0.45µm filtration, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00005 - 0.0010 g/m^3	2
Heavy metals, totals, trace As,Cd,Cr,Cu,Ni,Pb,Zn	Nitric acid digestion, ICP-MS, trace level	0.000053 - 0.0011 g/m^3	2
Nutrient Profile		0.0010 - 0.010 g/m^3	2
Polycyclic Aromatic Hydrocarbons Screening in Water, By Liq/Liq	Liquid / liquid extraction, SPE (if required), GC-MS SIM analysis [KBIs:4736,2695]	0.00010 - 0.0005 g/m^3	2
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	2
Total Digestion	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	2
Total Kjeldahl Digestion	Sulphuric acid digestion with copper sulphate catalyst.	-	2
Total Phosphorus Digestion	Acid persulphate digestion.	-	2
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd ed. 2012.	0.05 NTU	2
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	2
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 22nd ed. 2012.	3 g/m^3	2
Filtration for dissolved metals analysis	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	2
Dissolved Aluminium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.003 g/m^3	2
Total Aluminium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8.	0.0032 g/m^3	2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	2
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.021 g/m^3	2
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	2
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N). APHA 4500-NH_3 F (modified from manual analysis) 22nd ed. 2012.	0.010 g/m^3	2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	2
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D. (modified) 4500 NH_3 F (modified) 22nd ed. 2012.	0.10 g/m^3	2
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22nd ed. 2012.	0.004 g/m^3	2
Total Phosphorus	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NWASCA, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	2
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)	Incubation 5 days, DO meter, nitrification inhibitor added, dilutions, seeded. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 5210 B (modified) 22nd ed. 2012.	2 g O_2/m^3	2
Faecal Coliforms	Membrane Filtration, Count on mFC agar, Incubated at 44.5°C for 22 hours, Confirmation. Analysed at Hill Laboratories - Microbiology; 1 Clow Place, Hamilton. APHA 9222 D, 22nd ed. 2012.	1 cfu / 100mL	2

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Carole Rodgers-Carroll BA, NZCS
Client Services Manager - Environmental Division

Appendix 3 – Aquatic Macroinvertebrate Results

Rotokauri Structure Plan Industrial Development

Aquatic Invertebrate Assessment

20 June 2012

Boffa Miskell

Document Quality Assurance

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Prepared by:	Sharon De Luca Principal/Ecologist Boffa Miskell Limited	
Reviewed by:	Louise Clark Associate Principal/Ecologist Boffa Miskell Limited	
Status: FINAL	Revision / version: 0	Issue date: 20 June 2012
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1.0 Introduction

1.1 Background

Benthic macroinvertebrate samples were collected from soft bottom drains and streams by Stephanie Bathgate of Boffa Miskell on 20 June 2012. Boffa Miskell processed the samples and report below the results of taxonomic composition.

1.2 Objectives

The objectives of this report are to present the methods and results of aquatic macroinvertebrate sample processing.

2.0 Laboratory Analysis

2.1 Macroinvertebrate Samples

2.1.1 Processing

All samples were passed through a 500µm sieve to remove fine material. Contents of the sieve were then placed in a white tray and macroinvertebrates were identified under a dissecting microscope (10-40x) using the keys of Winterbourn *et al.* (2006) and NIWA's online resources.

Macroinvertebrate samples collected quantitatively were processed according to protocol 'P3: Full count with subsampling option' outlined in the Ministry for the Environment's 'Protocols for sampling macroinvertebrates in wadeable streams' (Stark *et al.* 2001).

2.2 Data Summaries and Metric Calculations

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of taxa: Reflects health of the community through a measurement of the variety of the taxa present. Taxonomic richness generally increases with increasing habitat diversity.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa: These insect groups are generally dominated by pollution sensitive taxa. In stony bed rivers, this index usually increases with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index (MCI) for soft-bottomed streams (MCI-sb)(Stark and Maxted 2007): These biotic indices have recently been developed specifically for use in soft-bottomed streams. The original MCI and SQMCI were developed for use in hard-bottomed streams based on sampling macroinvertebrates from riffle or run habitats, however their use has often been extended through a wide range of habitats including soft-bottomed areas. The soft-bottomed indices use the same principles as the hard-bottomed MCI and SQMCI indices, however new taxon-specific tolerance scores (between 1 and 10) have been derived specifically for soft-bottomed streams.

The MCI-sb uses the occurrence of specific macroinvertebrate taxa to determine the level of organic enrichment in a stream. Taxon scores are between 1 and 10, 1 representing species highly tolerant to organic pollution (e.g. worms and some dipteran species) and 10 representing species highly sensitive to organic pollution (e.g. most mayflies and stoneflies). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site. These scores can be interpreted in comparison with national standards (Table 2). For example, a low site score (e.g. 40) represents 'probable severe pollution' and a high score (e.g. 140) represents very 'clean' conditions.

$$MCI = \frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \times 20$$

Quantitative Macroinvertebrate Community Index (QMCI) (Stark 1985): The QMCI uses a similar approach as the MCI but weights each taxa score based on how abundant the taxa is within the community. Site scores range between 0 and 10. As for MCI, QMCI scores can be interpreted in the context of national standards (Table 2). QMCI scores were calculated for samples collected quantitatively and processed according to protocol 'P3: Full count with subsampling option'.

$$QMCI = \sum_{i=1}^{i=S} \frac{(\boldsymbol{n_i \times a_1})}{\boldsymbol{N}}$$

Where S = the total number of taxa in the sample, n_i is the number of invertebrates in the ith taxa, a_i is the score for the *i*th taxa, and N is the total number of invertebrates in the entire sample.

Table 2 *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI-sb	QMCI-sb, SQMCI-sb
Clean water	Excellent	> 120	> 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

3.0 Results

3.1 Macroinvertebrate results

The macroinvertebrate results are included below (Tables 4) and have also been forwarded to Louise Clark (Boffa Miskell Ltd) in electronic form.

Table 4 *Macroinvertebrate data.*

Taxon	MCI soft bottom	Murray Culvert			Te Kowhai Road		
COELENTERATA		Abundance	MCI	QMCI	Abundance	MCI	QMCI
Hydra	**1.6**	2	1.6	0.02		0	0.00
PLATYHELMINTHES	**0.9**	1	0.9	0.01	21	0.9	0.04
NEMATODA	**3.1**	1	3.1	0.02		0	0.00
OLIGOCHAETA	**3.8**	69	3.8	1.46	273	3.8	2.21
HIRUDINEA	**1.2**		0	0.00	2	1.2	0.01
CRUSTACEA							
Amphipoda	**5.5**		0	0.00	6	5.5	0.07
Ostracoda	**1.9**	3	1.9	0.03	3	1.9	0.01
INSECTA							
Plecoptera							
Trichoptera							
Hudsonema	**6.5**		0	0.00	1	6.5	0.01
Oxyethira	**1.2**	22	1.2	0.15		0	0.00
Odonata							
Austrolestes	**0.7**	2	0.7	0.01		0	0.00
Xanthocnemis	**1.2**	15	1.2	0.10	1	1.2	0.00
Hemiptera							
Microvelia	**4.6**		0	0.00	1	4.6	0.01
Sigara	**2.4**	18	2.4	0.24	2	2.4	0.01
Coleoptera							
Dytiscidae	**0.4**		0	0.00	1	0.4	0.00
Hydrophilidae	**8**		0	0.00	3	8	0.05
Liodessus	**4.9**		0	0.00	1	4.9	0.01
Diptera							
Ceratopogonidae	**6.2**		0	0.00	1	6.2	0.01
Chironominae	**3.8**	1	3.8	0.02		0	0.00
Chironomus	**3.4**		0	0.00	11	3.4	0.08
Hexatomini	**6.7**	1	6.7	0.04	6	6.7	0.09
Muscidae	**1.6**	1	1.6	0.01		0	0.00
Orthocladiinae	**3.2**		0	0.00	10	3.2	0.07

Stratiomyidae	**4.2**		0	0.00	1	4.2	0.01
Tanypodinae	**6.5**		0	0.00	7	6.5	0.10
Tanytarsus	**-**		0	0.00	23	-	0.00
Zelandotipula	**3.6**		0	0.00	3	3.6	0.02
Lepidoptera							
Collembola	**5.3**	1	5.3	0.03	1	5.3	0.01
ACARINA	**5.2**	1	5.2	0.03	1	5.2	0.01
MOLLUSCA							
Gyraulus	**1.7**	1	1.7	0.01		0	0.00
Physa = Physella	**0.1**	2	0.1	0.00	5	0.1	0.00
Potamopyrgus	**2.1**	38	2.1	0.44	3	2.1	0.01
Sphaeriidae	**2**	1	2	0.01	83	2	0.35
Total Abundance		**180**			**470**		
Taxonomic richness		**18**			**25**		
No. of Insect Taxa		**8**			**16**		
No of EPT Taxa		**1**			**1**		
%EPT abundance		**12.2**			**0.2**		
MCI-sb		**50.3**			**71.8**		
QMCI-sb		**2.6**			**3.2**		

4.0 References

Boothroyd, I.G. and Stark, J.D. 2000. *Use of invertebrates in monitoring.* Chapter 14 in Collier, K.J. and Winterbourn, M.J. eds. *New Zealand stream invertebrates: ecology and implications for management.* New Zealand Limnological Society, Christchurch. Pp. 344-373.

Stark, J.D. 1993. *Performance of the Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values.* New Zealand Journal of Marine and Freshwater Research. 27: 463-478.

Stark J.D. and Maxted, J.R. 2007. *A biotic index for New Zealand's soft-bottomed streams.* New Zealand Journal of Marine and Freshwater Research. 41: 43-61.

Stark, J.D., Boothroyd, I.K.G., Harding, J.S., Maxted, J.R. and Scarsbrook, M.R. 2001. *Protocols for sampling macroinvertebrates in wadeable stream.* New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment.

Winterbourn, M.J., Gregson, K.L.D. and Dolphin, C.H. 2006. *Guide to the aquatic insects of New Zealand.* Bulletin of the Entomological Society of New Zealand. 14.

T15161 (Mangaheka)

Summary of Freshwater Macroinvertebrate Sample Processing & Results

April 2016

ryderconsulting
environment + planning + project management

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prepared for Boffa Miskell by Ryder Consulting Limited

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Table of Contents

1. Introduction

Preserved benthic macroinvertebrate samples were provided to Ryder Consulting Limited by Boffa Miskell. Boffa Miskell staff collected these samples in April 2016. Ryder Consulting Limited was engaged to process the samples, and report the results of taxonomic composition and abundance.

2. Laboratory Analysis

2.1 Processing

In the laboratory, the samples were passed through a 500 µm sieve to remove fine material. Contents of the sieve were then placed in a white tray and macroinvertebrates were identified under a dissecting microscope (10-40x) using criteria from Winterbourn *et al.* (2006).

2.2 Data summaries and metric calculations

For each site, benthic macroinvertebrate community health was assessed by determining the following characteristics:

Number of invertebrates: The total number of individuals from all taxa groups per sample. Invertebrate abundance gives an indication of benthic production.

Number of taxa: A measurement of the number of taxa present.

Number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, percentage of the total number of taxa comprising EPT taxa (% EPT taxa), and percentage of the total abundance comprising EPT taxa (% EPT abundance): These insect groups are generally dominated by invertebrates that are indicative of higher quality conditions. In stony bed rivers, these indexes usually increase with improved water quality and increased habitat diversity.

Macroinvertebrate Community Index for soft-bottomed streams (MCI-sb) and Quantitative MCI for soft-bottomed streams (QMCI-sb) (Stark and Maxted 2007): These biotic indices have been developed specifically for use in soft-bottomed streams. The original MCI and QMCI were developed for use in hard-bottomed streams based on sampling macroinvertebrates from riffle or run habitats, however their use has often been extended through a wide range of habitats including soft-bottomed areas. The soft-bottomed indices use the same principles as the hard-bottomed MCI and QMCI indices, however new taxon-specific tolerance scores (between 1 and 10) have been derived specifically for soft-bottomed streams (Stark and Maxted 2007).

The MCI-sb site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site.

$$\text{MCI-sb} = \left(\frac{\text{Sum of taxa scores}}{\text{Number of scoring taxa}} \right) \times 20$$

The QMCI-sb is calculated as:

$$\text{QMCI-sb} = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

Where S = the total number of taxa in the sample, n_i is the number of invertebrates in the ith taxa, a_i is the score for the *i*th taxa, and N is the total number of invertebrates for the entire sample.

As for MCI and QMCI, MCI-sb and QMCI-sb scores can be interpreted in the context of national standards (Table 1).

Table 1 *Interpretation of macroinvertebrate community index values from Boothroyd and Stark (2000) (Quality class A) and Stark and Maxted (2007) (Quality class B).*

Quality Class A	Quality Class B	MCI-sb	QMCI-sb
Clean water	Excellent	≥ 120	≥ 6.00
Doubtful quality	Good	100 – 119	5.00 – 5.99
Probable moderate pollution	Fair	80 – 99	4.00 – 4.99
Probable severe pollution	Poor	< 80	< 4.00

3. Results

3.1 Macroinvertebrate results

The macroinvertebrate results are included below and have also been forwarded to Boffa Miskell in electronic form (Excel spreadsheet).

		Mangaheka		
TAXON	**MCI-sb score**	**1A**	**1B**	**1C**
ACARINA	5.2		1	
COLEOPTERA				
Hydraenidae	6.7	1	1	
Hydrophilidae	8.0			1
COLLEMBOLA	5.3	2		
CRUSTACEA				
Cladocera (*Simocephalus*)	0.7			6
Copepoda (Cyclopoida)	2.4			217
Ostracoda	1.9	67	3	19
Paracalliope fluviatilis	5.5	4	12	13
DIPTERA				
Chironomus species	3.4			1
Orthocladiinae	3.2	1		5
HEMIPTERA				
Sigara species	2.4	4		
MOLLUSCA				
Lymnaeidae	1.2	2	3	3
Physa / Physella species	0.1	9		3
Potamopyrgus antipodarum	2.1	22	13	18
Sphaeriidae	2.9	1	1	
ODONATA				
Xanthocnemis zealandica	1.2	1	1	1
OLIGOCHAETA	3.8		4	1
PLATYHELMINTHES	0.9	249	112	47
TRICHOPTERA				
Oxyethira albiceps	1.2	55	39	18
Number of invertebrates		418	190	353
Number of taxa		13	11	14
Number of EPT taxa		1	1	1
% EPT taxa		8	9	7
% EPT abundance		13	21	5
MCI-sb score		53.2	59.3	50.9
QMCI-sb score		1.3	1.5	2.2

4. References

Boothroyd, I.G. and Stark, J.D. 2000. Use of invertebrates in monitoring. Chapter 14 in Collier, K.J. and Winterbourn, M.J. eds. New Zealand stream invertebrates: ecology and implications for management. New Zealand Limnological Society, Christchurch. Pp. 344-373.

Stark, J.D. and Maxted, J.R. 2007. A biotic index for New Zealand's soft-bottomed streams. *New Zealand Journal of Marine and Freshwater Research*. **41**: 43-61.

Winterbourn, M.J., Gregson, K.L.D. and Dolphin, C.H. 2006. Guide to the aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand*. **14**.