

Ecological impacts of the proposed C4 Growth Cell

Cambridge, Waikato

Prepared for Mitchell Daysh Limited

July 2019

Prepared by:

Eimear Egan

Cindy Baker

For any information regarding this report please contact:

Cindy Baker

Principal Scientist - Freshwater Fish

Group Manager, Freshwater Ecology

+64-7-856 1774

cindy.baker@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd

PO Box 11115


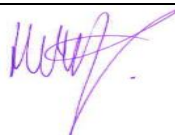

Hamilton 3251

Phone +64 7 856 7026

NIWA CLIENT REPORT No: 2019206HN

Report date: July 2019

NIWA Project: SCJ202GOV

Quality Assurance Statement		
	Reviewed by:	Paul Franklin
	Formatting checked by:	Rachel Wright
	Approved for release by:	Scott Stephens

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Executive summary

Mitchell Daysh are developing the Structure Plan for the C4 Growth Cell for Waipa District Council. The proposed C4 Growth Cell is 66ha and will be situated on the Leamington side of Cambridge with capacity for 790 dwellings. Mitchell Daysh wish to ensure that existing waterways can be used to discharge stormwater. Prior to developing the Structure Plan, Mitchell Daysh have contracted NIWA to assess freshwater ecological values that may be impacted by the C4 Growth Cell development. The proposed C4 Growth Cell development may alter the hydrological regime of the C4 Stream and, therefore, affect freshwater habitats and species. In this regard, a site visit and desktop ecological assessment was undertaken on freshwater habitats and species that may be impacted by the C4 Growth Cell development.

The C4 Growth Cell has one unnamed tributary stream within its area of influence (herein referred to as C4 Stream) and was the focus of the site assessment. The C4 Stream drains primarily urban and industrial land, although the C4 Growth Cell development largely involves converting pastoral land to residential properties. The upper reaches of the stream were characterised by more instream habitat heterogeneity containing riffle, run, pool and ephemeral seep habitats along with a wide floodplain and intact riparian margin compared to the lower reaches. Within the wider landscape, the canopy cover of the upper C4 Stream is more mature and established compared to neighbouring freshwater sites. It is likely that the most upstream habitats above the lake have the potential to accommodate a range of native fish species including black mudfish and large bodied galaxiids (banded kōkopu and giant kōkopu).

Records from the New Zealand Freshwater Fish Database showed only two species; longfin eel (declining) and shortfin eel (not threatened) have been found in the C4 Stream. Within the wider area of the C4 Stream, 11 native and 7 non-native freshwater fish species have been recorded. However, only two prior fishing records existed, neither of which surveyed the representative habitats present, and one record was 25 years old. Therefore, these existing records may not accurately represent the fish communities within the wider C4 Stream.

A culvert was identified that may be an impediment to fish passage and limit fish communities, but this could not be ascertained during the site visit. There appeared to be poor hydrological connectivity between the upstream and downstream habitats during the site visit. This is because little water movement was evident through the culvert which would have been expected given the storage capacity of the lake directly upstream. If the culvert were blocked, then additional stormwater discharges to the C4 Stream may restrict movement of stormwater through the culvert.

The magnitude of any hydrological modifications and their subsequent effects on the C4 Stream are unknown as the stormwater management plan has not been developed. No known hydrological data exists for the C4 Stream and changes in hydrological characteristics from stormwater discharges cannot be evaluated. Overall, the ecological integrity (e.g., native freshwater fish and instream habitat diversity) of the C4 Stream cannot be fully understood based on the existing data. Future recommendations are to:

- Complete updated ecological surveys to describe the freshwater fish and macroinvertebrate communities in the C4 Stream, and;
- A further assessment of the culvert under Cambridge Road to determine if it is an impediment to fish passage and to stormwater discharges;

- Collect instream hydrological data to support flow modelling and the effects of stormwater discharges on the C4 Stream;
- Consider an ecological flow assessment using RHYHABSIM or similar physical habitat model to enable habitat changes with an altered flow regime to be more accurately assessed.

1 Introduction

1.1 Background

In 2009, Waipa District Council (WDC) developed a Growth Strategy for 2050 as part of the Waipa District Plan¹. This growth strategy was developed in response to rapid population growth within the Waipa District and to respond to changing national and regional policy direction. As part of the 2050 Growth Strategy, a number of residential Growth Cells were identified in Cambridge (Figure 1-1). The Growth Strategy 2050 was modified and accepted in March 2019 as part of Plan Change 5, and it was confirmed that the C4 Growth Cell will be a Residential Zone.

The proposed C4 Growth Cell is 66ha in size and situated south-west of Cambridge near Leamington (Figure 1-2). The C4 Growth Cell is intended for residential development with a capacity for 790 dwellings and is an alternative, along with Growth Cells C5 and C11. It is anticipated the C4 Growth Cell development will be completed by 2035.

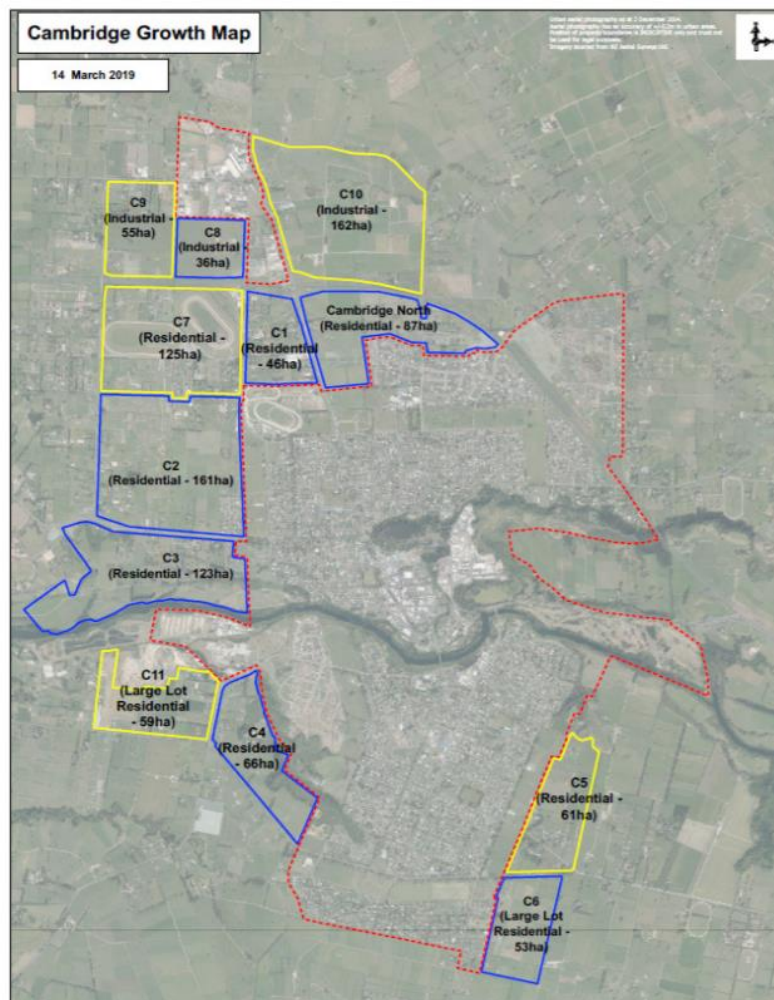


Figure 1-1: The location of the Growth Cells designated for Cambridge, Waikato.

¹ <https://www.waipadc.govt.nz/our-council/Waipac2050/wdc-part-operative/Variations/Pages/Plan-Change-5---Waipa-2050-Growth-Strategy.aspx>

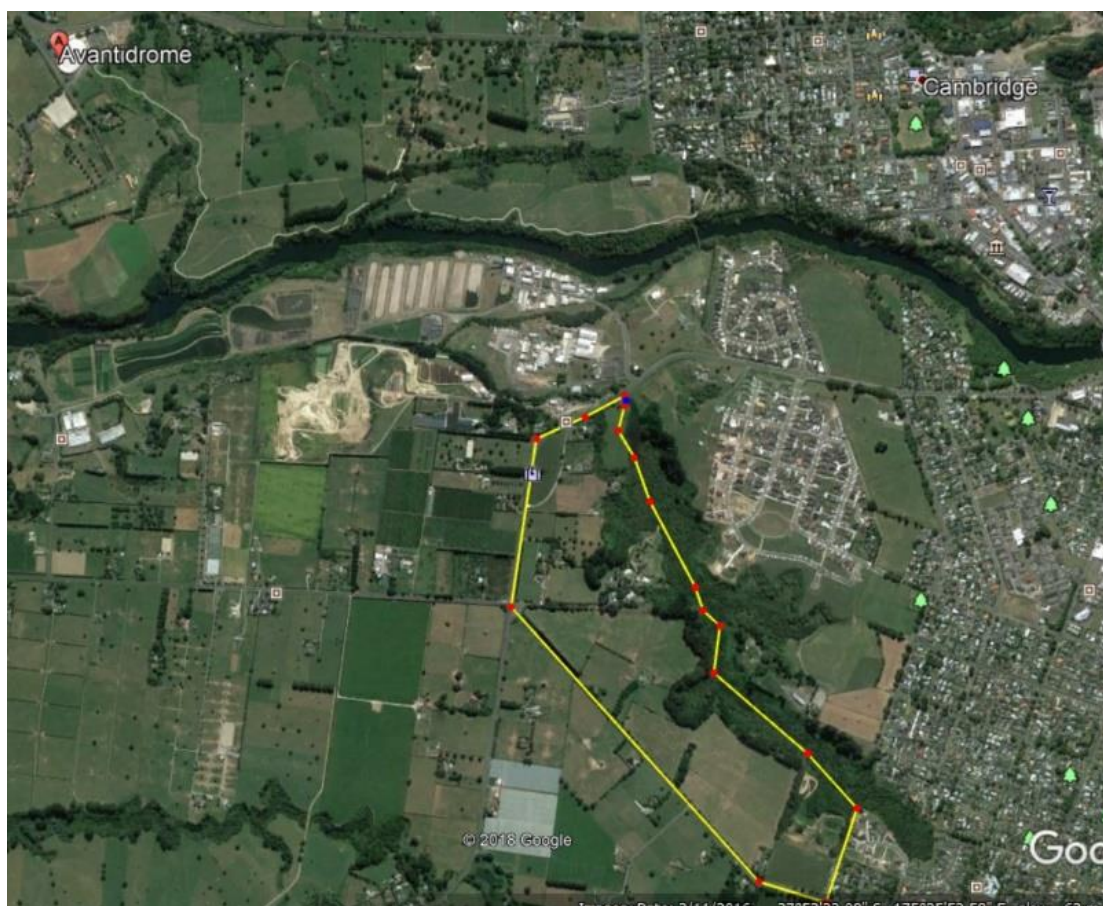


Figure 1-2: The boundary of the C4 Growth Cell is outlined in yellow. The un-named stream (herein referred to as C4 Stream) runs parallel to eastern boundary of the C4 Growth Cell.

Mitchell Daysh Limited (“Mitchell Daysh”) has been engaged by WDC in a project management capacity. Their task is to produce a Structure Plan which will determine the urban form, use and manner, in which infrastructure can be efficiently and cost-effectively developed to facilitate residential development in the C4 Growth Cell. The Structure Plan will also include factors such as connectivity to existing roading network/urban areas (including cycle and pedestrian linkages) and reserve provisions. The timeframe for the development of the Structure Plan by Mitchell Daysh is October 2019.

1.2 Environmental context

A key part to developing the Structure Plan is to identify the ecological values associated with the C4 Growth Cell. In this regard, an ecological assessment is required for WDC to understand the existing freshwater environments that must be considered prior to the development and the effects of the stormwater management plan. The proposed developments for the C4 Growth Cell primarily involve converting pastoral land to residential properties. The anticipated changes on freshwater ecosystems from creating urban areas, and the subsequent increase in impervious surfaces include:

- a reduction in base flows;
- a flashier flow regime with shorter durations and higher peaks for elevated flows;
- elevated concentrations of nutrients and contaminants;

- altered channel morphology and stability; and,
- reduced biotic richness, with increased dominance of tolerant species (Walsh et al. 2012).

To protect aquatic stream health and integrity, excess stormwater needs to be effectively managed along with ensuring appropriate base flows for the target biota are maintained. In that regard, Mitchell Daysh have contracted NIWA to carry out an initial ecological assessment to inform the Structure Plan for the C4 Growth Cell.

1.3 Report scope

The purpose of this report is to provide Mitchell Daysh with ecological information about the potential impacts of the C4 Growth Cell development on freshwater ecosystems. The timeframe for the development of the Structure Plan by Mitchell Daysh is October 2019. To meet this deadline, Mitchell Daysh understand that ecological surveys of waterways are not recommended during the winter months. Considering this, Mitchell Daysh have specified the scope of the ecological assessment and have specifically requested NIWA to:

1. Undertake a site visit of freshwater environments relevant to the C4 Growth Cell development;
2. Review existing ecological information/literature with respect to the waterways within and surrounding the project area;
3. Prepare a report detailing the existing environment based on the site visit and literature review;
4. Identify any potential ecological issues or constraints that may arise from the C4 Growth Cell Development;
5. Detail any further work and information required to accurately assess the impacts of stormwater discharges on freshwater ecosystems.

It is recognised by Mitchell Daysh that a detailed environmental assessment will be required in the future as part of the resource consenting process for the C4 Growth Cell. This detailed study is beyond the scope of this report. Therefore, this report serves to provide the background information for Mitchell Daysh to develop the relevant Structure Plan while being cognisant of the effects on aquatic environments.

2 Methods

2.1 Site visit

A site visit of freshwater habitats that may be impacted by the proposed C4 Growth Cell was undertaken on 8th June 2019. The C4 Growth Cell has one key unnamed tributary stream within its area of influence (herein referred to as C4 Stream; Figure 2-1) and was the focus of the site assessment. The C4 Stream runs in a northerly direction and discharges to the Waikato River. The C4 Stream is approximately 143 km from the Waikato River mouth. The stream is approximately 3.17 km in length with a catchment area of 8.03 km². The catchment geology is predominantly soft sediment.

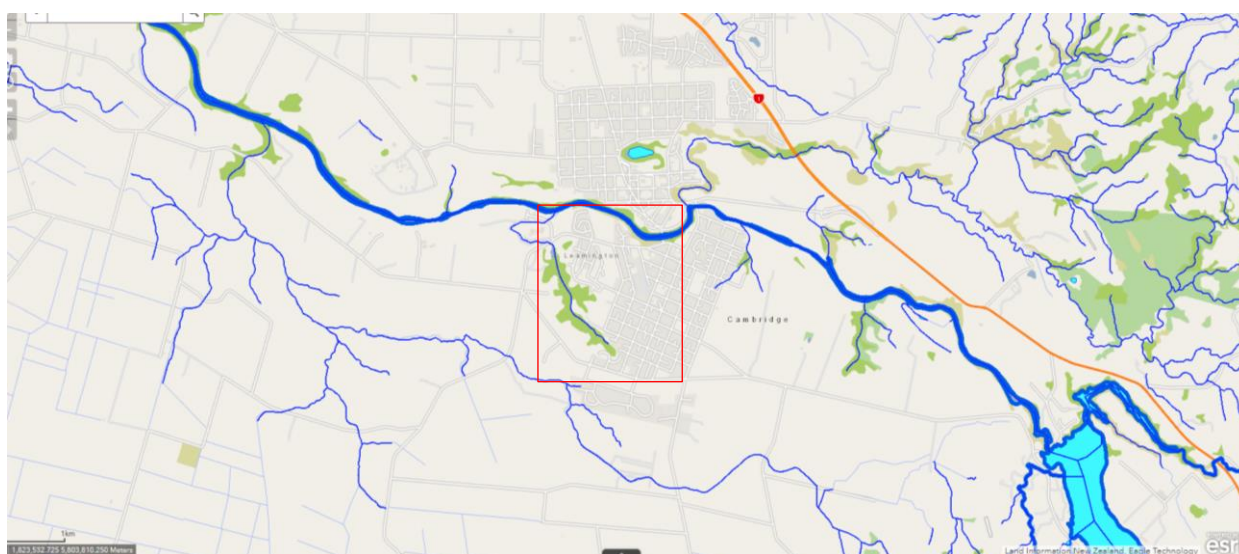


Figure 2-1: Location of the C4 Stream (defined by red box) west of the Leamington township. Freshwater environments in the wider landscape are denoted by the blue lines.

For the visual assessment, the C4 Stream was subdivided into two sections herein referred to as upper and lower reaches with three-four sites surveyed in each reach (Figure 2-2). These reaches were delineated by changes in habitat types, enabling longitudinal changes in ecological values along the C4 Stream to be characterised. The selection of sites within each reach was constrained by ease of access and permission from land owners. The structure and integrity of the freshwater habitats at each of the sites in Figure 2-2 was visually assessed.

Potential impediments to fish passage (e.g., culverts, fords) were identified and the inlets and outlets of instream structures were inspected where possible. Barriers that prevent or delay migrations are one of the greatest threats to New Zealand's freshwater fish as connectivity between habitats can be critical to ensuring the long-term success of fish populations. Barriers to migration can restrict access to habitats required for foraging and feeding, predator avoidance, shelter, and spawning (Gibson et al. 2005). Lack of access to these habitats, particularly for migratory species, can ultimately lead to a reduction in recruitment, population decline, and a loss of biodiversity (e.g., Jellyman and Harding 2012).

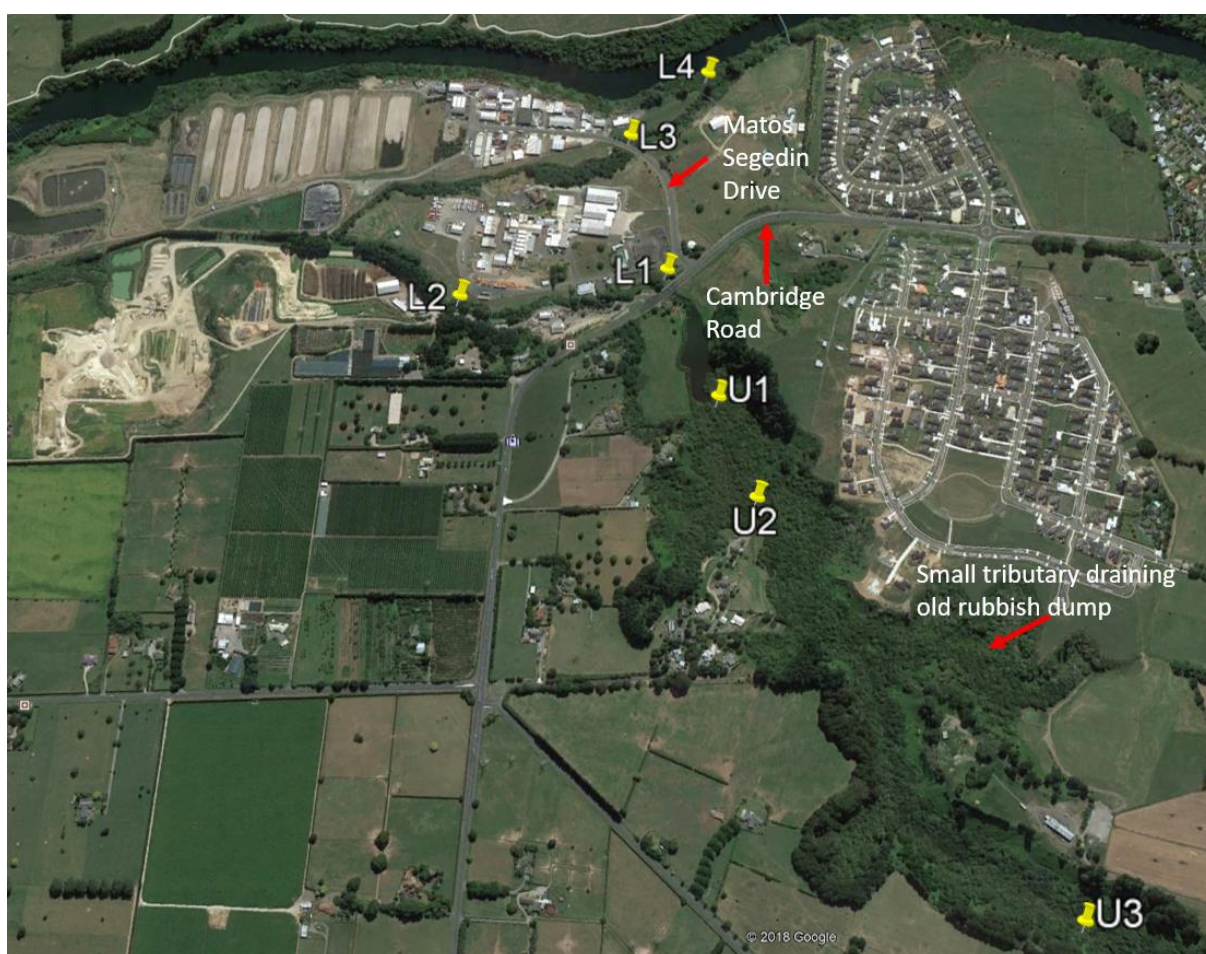


Figure 2-2: Location of the upper (U) and lower (L) sites visited in the C4 Stream that runs parallel to the eastern boundary of the C4 Growth Cell. A small tributary draining an old rubbish dump is shown as well as Cambridge Road and Matos Segedin Drive.

2.2 Review of existing ecological information

2.2.1 New Zealand Freshwater Fish Database Records

The New Zealand Freshwater Fish Database (NZFFD) was inspected to identify fish species that have previously been recorded in the C4 Stream and neighbouring tributaries of the Waikato River. Data stored in the NZFFD include the location of sample sites, the fish species present, as well as information on their abundance, size, sampling methods and a physical description of each site where records exist.

Fish records from the NZFFD can also be used to identify species distributions above and below potential barriers to fish movements (e.g., culverts). The pattern of freshwater fish distributions, together with knowledge of their migrations and movements can ascertain if fish barriers within the study area are potentially impeding fish movement.

2.2.2 Native freshwater fish habitats and ecology

The conservation status of New Zealand's freshwater fish was recently reviewed by Dunn et al. (2018). This constitutes New Zealand's current threat ranking for freshwater fishes. For freshwater fish species identified within the C4 Stream and wider area, their threat status was reported to help

evaluate the ecological integrity of the C4 Stream. In the context of the C4 Growth Cell development, the most important information with respect to each native freshwater fish species is to:

- Understand the nature and timing of species movements and migrations;
- Understand the habitat requirements for spawning and rearing;
- Understand the environmental cues (i.e., hydrological regime) required for different life stages (e.g., spawning, foraging).

2.2.3 Predicted hydrological, physical and ecological characteristics of the C4 Stream

The New Zealand River Maps tool (<https://shiny.niwa.co.nz/nzrivermaps/>) was used to extract predicted hydrological, physical and ecological characteristics of the C4 Stream. At present, there is no gauging station on the C4 Stream and consequently, there are no empirical data available to characterise the instream hydrological conditions. The NZ River Maps tool provides the ability to visualise national-scale predictions of metrics describing hydrology, ecology, water quality and landscapes. These predictions have been generated by NIWA and represent a static snapshot of predicted values across all New Zealand river reaches. Values were extracted for two reaches, one situated in the upper site (NZ Reach number 3020716) and one in the lower site (NZ Reach number 3020374).

Seven predicted flow metrics were extracted for the C4 Stream with their associated descriptions (see Table A-1). Predicted flow duration curves were also extracted from NZ River Maps. Flow duration curves (FDCs) are a useful tool for characterising hydrological regimes and flow variability as they represent the relationship between magnitude and frequency of flow by defining the proportion of time for which any discharge is equalled or exceeded. (Booker and Snelder, 2012).

2.3 Potential effects of stormwater discharge on freshwater ecosystems

The design details of the C4 Growth Cell stormwater system, and subsequent outfall to the Waikato River, are yet to be finalised. Therefore, an analysis of the anticipated effects of stormwater discharges on the relevant freshwater ecosystems was limited. We, therefore, analyse the potential effects of stormwater discharges on aquatic communities more generally and focus the analysis in the discussion on species identified in the analysis of the NZFFD records (see section 2.2.1).

3 Results

3.1 Site visit

3.1.1 Upper section (sites U1, U2 and U3)

The Upper section of the C4 Stream at site U3 (see Figure 2-2) was relatively heterogeneous. There were faster flowing riffle habitats and deeper pools that were formed by fallen trees (Figure 3-1). The substrate was largely comprised of gravels and sand as well as organic leaf matter. The canopy was mature and contained a mix of both native and exotic species. The riparian vegetation was a mixture of native and exotic species but dominated by the weed wandering willy (*Tradescantia fluminensis*).

Along the margins of the C4 main stem, seepages and ephemeral/wetland habitats were identified (see Figure 3-1). During high flow events, these marginal habitats likely become inundated, especially considering the wide flood plain that exists. These marginal habitats are, therefore, likely connected to the main stem of the C4 Stream during periods of higher flows.

At site U2 (Figure 2-2), the habitat transitioned into a more degraded state compared to the more intact habitats found in the uppermost site (site U3). The canopy and riparian cover were increasingly dominated by willows, and deep deposits of finer sediments were observed in the main stem as well as within the bankside riparian vegetation. Riffle and pool habitats were also present here creating instream habitat heterogeneity. The network of seepages and ephemeral habitats were also observed at site U2. A man-made lake (approx. 6,931 m²) was situated at site U1 (Figure 2-2) and is visible from Cambridge Road.



Figure 3-1: Range of freshwater habitat types identified in the upper section of the C4 Stream including riffles, pools and ephemeral seeps. Note the overhanging vegetation.

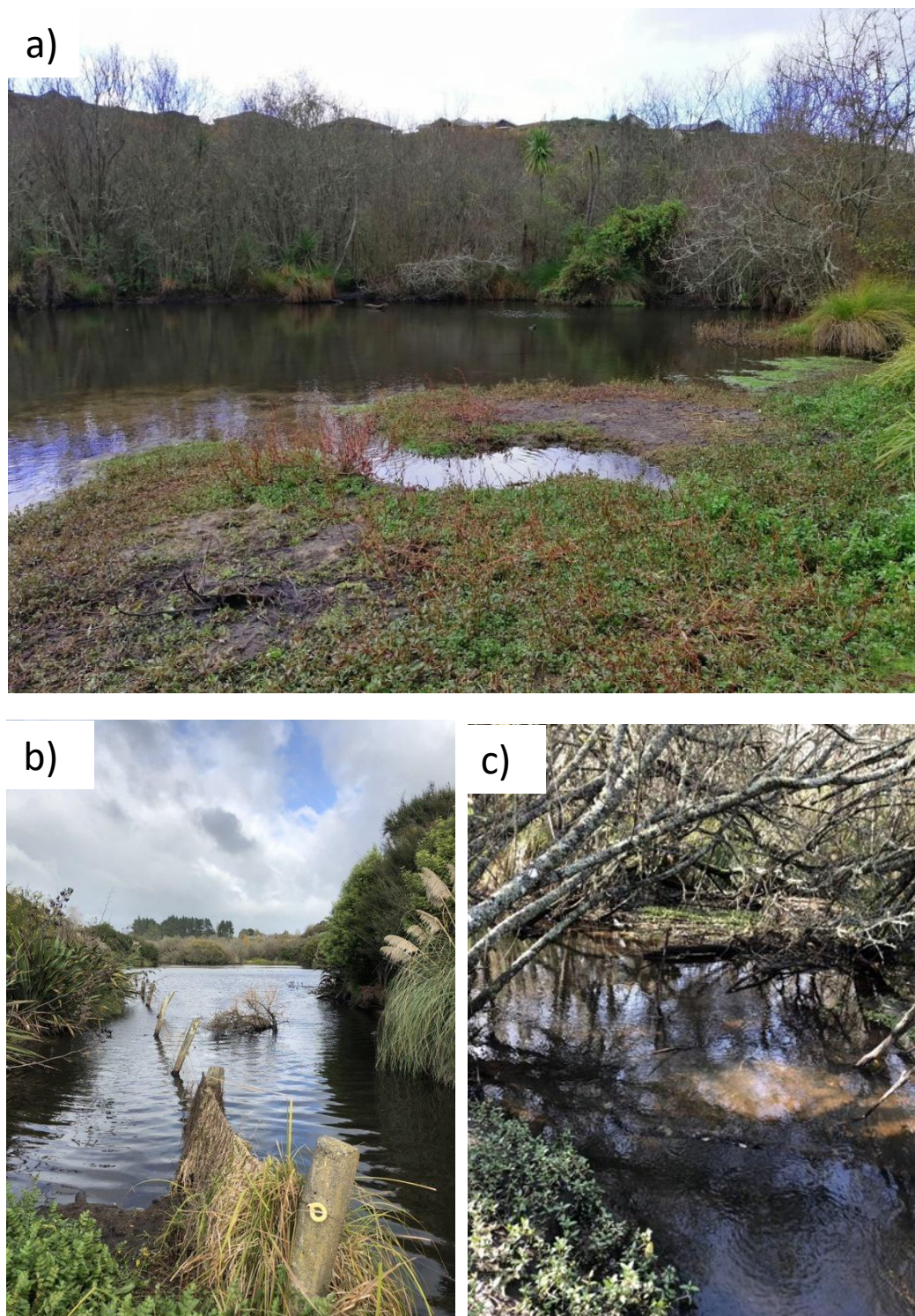


Figure 3-2: Upper section of the C4 Stream showing a) the upper lake; b) the lower lake and c) riffle habitats with overhanging vegetation.

3.1.2 Lower section (sites L1, L2, L3, L4)

The land use in the Lower section of the C4 Stream was dominated by industrial development. It was difficult to access the stream because it was largely overgrown with weeds, the banks were steep, and the river became increasingly incised (Figure 3-3). There was evidence that livestock have access to the stream in this section as well as dumping of metal scraps (Figure 3-3). A culvert exists under Matos Segedin Drive (Figure 3-4).

3.2 Fish passage assessment

Two culverts are present in the C4 Stream that could be fish passage barriers. The first culvert was located downstream from the lake where it connected the stream under Cambridge Road (Figure 3-4). The structure could not be assessed directly as both the inlet and outlet were submerged and among dense weeds and mud (Figure 3-5). Although there was a very small amount of water movement seen at the outlet (Figure 3-5), higher flows were expected considering the size and storage capacity of the lake upstream. The culvert may, therefore, be partially blocked and represent an impediment to fish movements. Further investigation of the structure is required to determine if it is a migration barrier for different fish species (see section 4.1.3).

A second culvert is located underneath Matos Segedin Drive (Figure 3-4). At the time of the assessment, this structure did not appear to be an impediment to fish passage (Figure 3-6). However, the hydrological regime of the C4 Stream may change with the development of the C4 Growth Cell and anticipated stormwater inputs will change both base flows and the magnitude and duration of flood flows. Considering many of New Zealand's native freshwater fish species are small bodied and some are weak swimmers, seemingly small obstructions and poor hydrological connectivity (i.e. due to changes in flow) can severely impede fish passage (Franklin et al. 2018).



Figure 3-3: Lower section of the C4 Stream showing steeper banks and more incised stream. The riparian vegetation was compromised and is dominated by weeds.

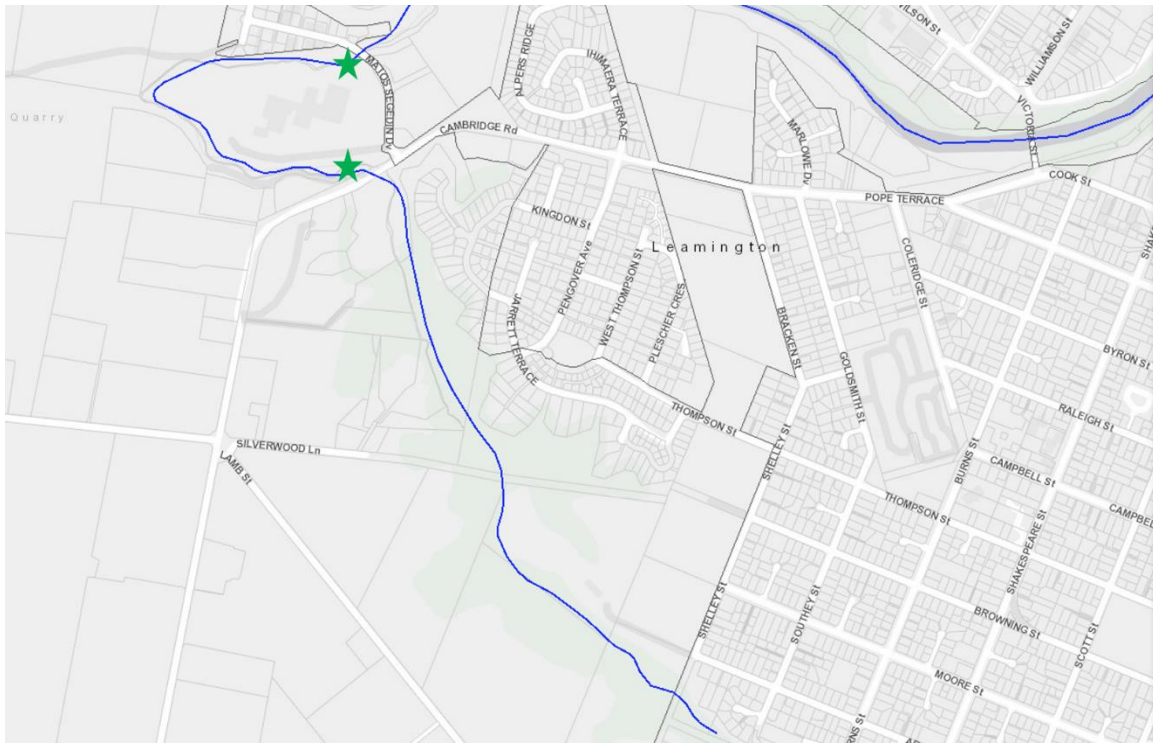


Figure 3-4: Map showing the locations of the two culverts (denoted by green stars) at Cambridge Road and Matos Segedin Drive.



Figure 3-5: The first potential fish passage barrier identified at the upper section of the C4 Stream where it intersects Cambridge Road. Both the inlet and outlet of the structure could not be seen or felt under the water.



Figure 3-6: Culvert in the C4 Stream under Matos Segedin Drive.

3.3 Review of existing ecological information

3.3.1 Species records from the New Zealand Freshwater Fish Database

There are two records in the NZFFD that found longfin eels (*Anguilla dieffenbachii*) and shortfin eels (*Anguilla australis*) in the C4 Stream (Figure 3-7). One record from 2016 found one shortfin eel in the lake above Cambridge Road, but no details on fishing method or area were provided (Figure 3-7). The second record from 1994 found shortfin eels were abundant and longfin eels were occasional in a 30 m² area surveyed with single pass electric fishing. This record appears to be located on a small tributary feeding into the mainstem of the C4 Stream above Cambridge Road (Figure 2-2; Figure 3-7). This small tributary drains an old landfill (now a dog park) and stormwater pond, and the stream contained high levels of iron floc that was not observed in the mainstem of the C4 Stream.

These fishing records show a low biodiversity within the C4 Stream given that 18 species of freshwater fish are known to occur in the wider area. Eleven of these are native species (Figure 3-7) and seven are introduced (Figure 3-8). Five of the native freshwater fish species identified within the wider study are classified as At Risk – Declining (īnanga, giant kōkopu, black mudfish, longfin eel and torrentfish) while six native freshwater fish are classified as Not Threatened (Table 3-1). The low biodiversity recorded in the C4 Stream may be because of several reasons:

- The record in the upper stream section is 25 years old;
- The fishing location in the smaller tributary was not representative of the habitat heterogeneity observed in the mainstem during the site visit;
- The fishing method was inadequate to survey the full fish community present;
- The culvert under Cambridge Road represents a migration barrier.

It is likely that all factors are responsible for the low fish biodiversity. In particular, fish sampling protocols indicate a 150 m stretch of stream is needed to be electric fished to ensure all habitats will be represented (Joy et al. 2013). That said, the fact that only eels, the two species most adept at passing instream obstacles were found upstream of the Cambridge Road culvert indicates the culvert requires further assessment to determine if it is indeed a fish passage barrier.

Of importance is the variety of habitats present in the C4 Stream, presently there are no fishing records from the lower more degraded section of the stream below Cambridge Road, the lake immediately above Cambridge Road, and the wetland/ephemeral and perennial habitats in the upper reaches of the main stem. If there are no passage barriers, the lake appeared suitable habitat for colonisation of undesirable exotic species such as koi carp, catfish, gambusia, and rudd. The infestation of these species would lower the ecological value of the lake and wider stream system. Based on the habitat types present, an updated fish survey of the C4 Stream targeting the aforementioned habitats is deemed necessary to assess its current ecological values and predict the impacts of the proposed growth cell.

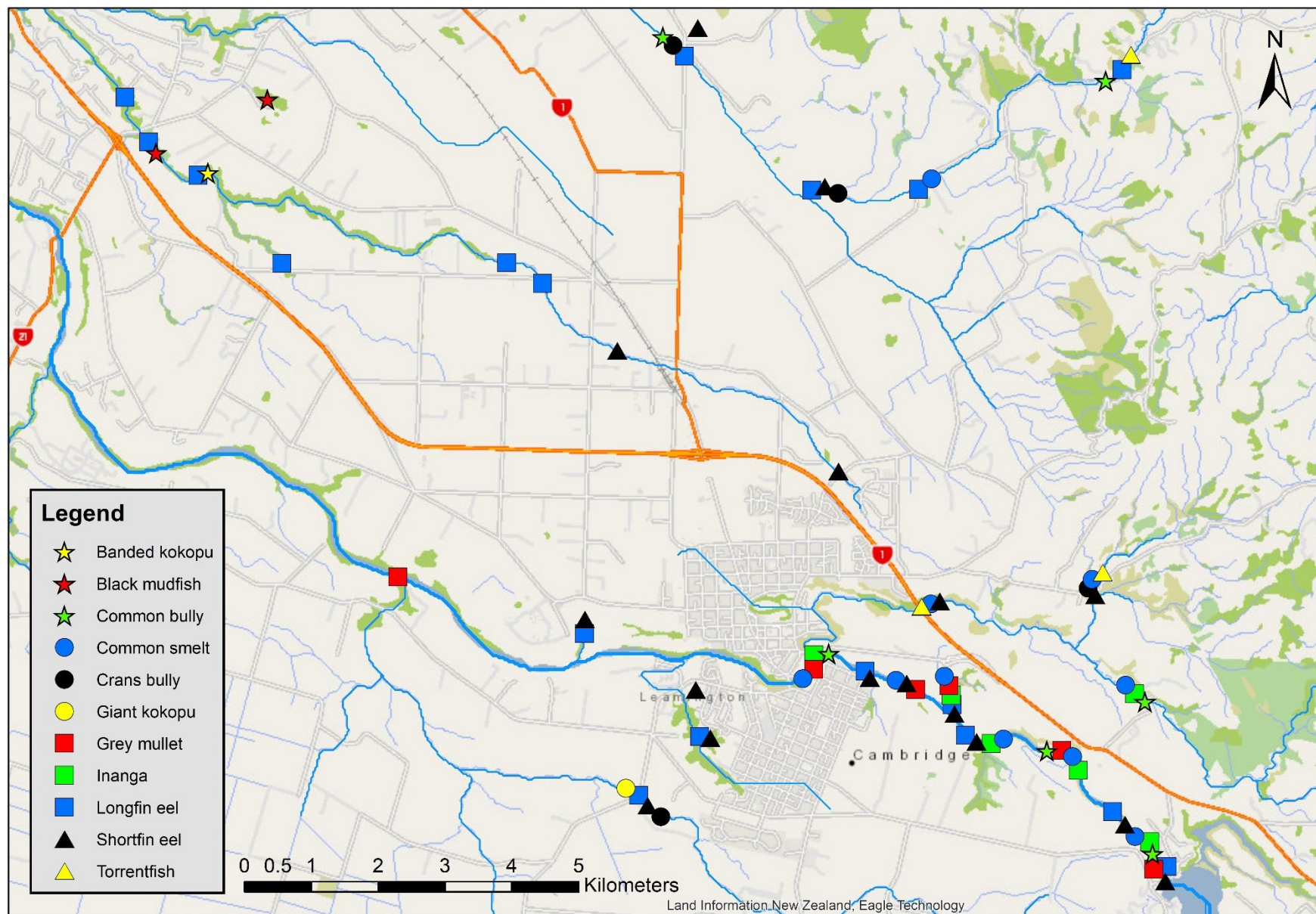


Figure 3-7: Map showing the distribution of native freshwater fish species in the C4 Stream and wider area.

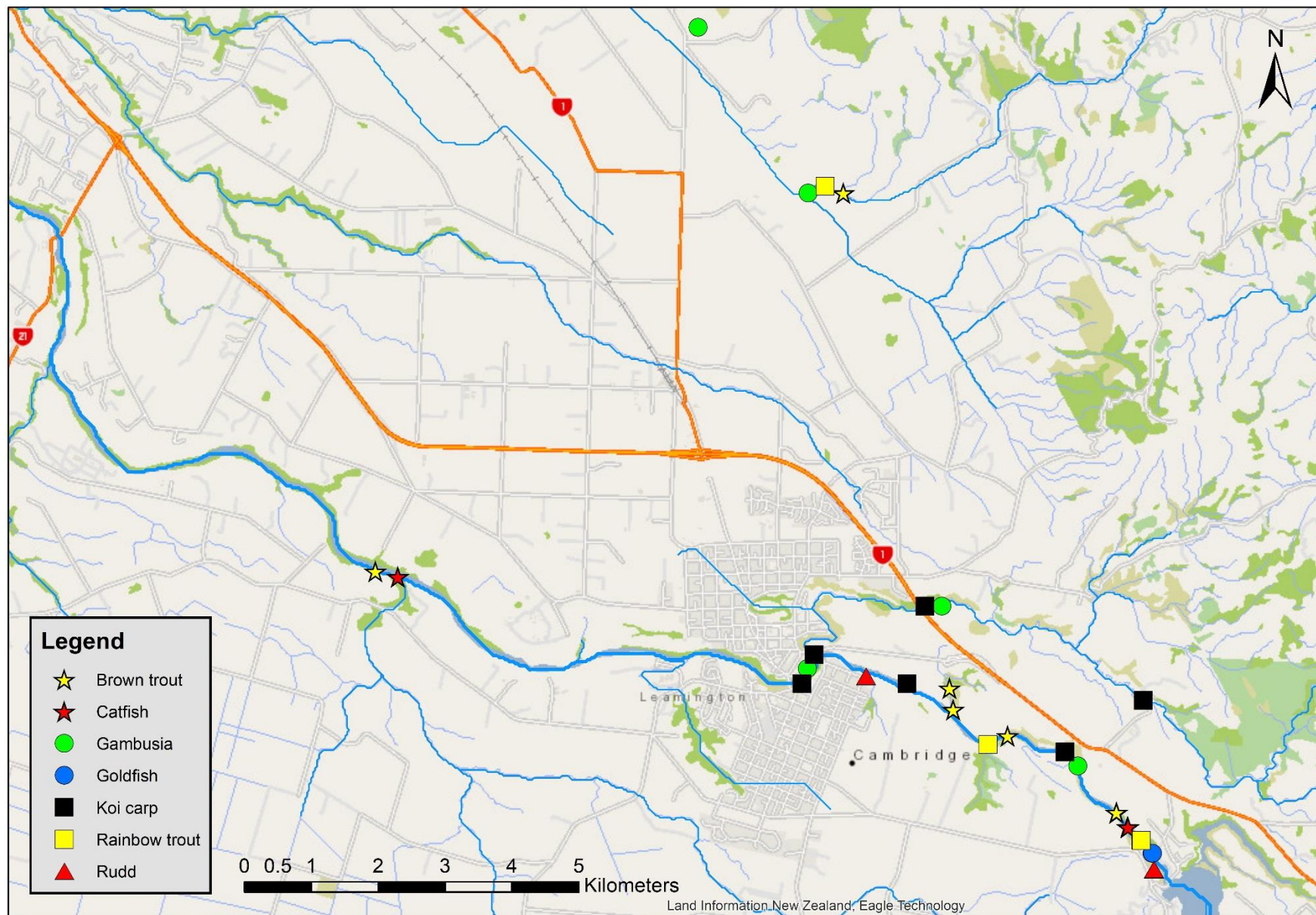


Figure 3-8: Map showing the distribution of exotic freshwater fish species in the C4 stream and in the wider area.

Table 3-1: Freshwater fish species that have been recorded in the New Zealand Freshwater Fish Database from the C4 Stream and surrounding area. Species are organised in alphabetical order by their common name.

Native/introduced	Common name	Scientific name	Life history type	Conservation status
Native	Banded kōkopu	<i>Galaxias fasciatus</i>	Diadromous and Non-diadromous	Not Threatened
	Black mudfish	<i>Neochanna diversus</i>	Non-diadromous	At Risk - Declining
	Common bully	<i>Gobiomorphus cotidianus</i>	Diadromous and Non-diadromous	Not Threatened
	Common smelt	<i>Retropinna retropinna</i>	Diadromous and Non-diadromous	Not Threatened
	Cran's bully	<i>Gobiomorphus basalis</i>	Non-diadromous	Not Threatened
	Giant kōkopu	<i>Galaxias argenteus</i>	Diadromous and Non-diadromous	At Risk - Declining
	Grey mullet	<i>Mugil cephalus</i>	Diadromous	Not Threatened
	Īnanga	<i>Galaxias maculatus</i>	Diadromous and Non-diadromous	At Risk - Declining
	Longfin eel	<i>Anguilla dieffenbachii</i>	Diadromous	At Risk - Declining
	Shortfin eel	<i>Anguilla australis</i>	Diadromous	Not Threatened
	Torrentfish	<i>Cheimarrichthys fosteri</i>	Diadromous	At Risk - Declining
Introduced	Brown trout	<i>Salmo trutta</i>	Non-diadromous	Introduced and naturalised
	Catfish	<i>Ameiurus nebulosus</i>	Non-diadromous	Introduced and naturalised
	Gambusia	<i>Gambusia affinis</i>	Non-diadromous	Introduced and naturalised
	Goldfish	<i>Carassius auratus</i>	Non-diadromous	Introduced and naturalised
	Koi carp	<i>Cyprinus carpio</i>	Non-diadromous	Introduced and naturalised
	Rainbow trout	<i>Oncorhynchus mykiss</i>	Non-diadromous	Introduced and naturalised
	Rudd	<i>Scardinius erythrophthalmus</i>	Non-diadromous	Introduced and naturalised

3.4 Overview of key species ecology

The ecology and life histories of eight native freshwater fish species (longfin eel; shortfin eel; banded kōkopu; giant kōkopu; īnanga; black mudfish; smelt and common bullies) are summarised below (Table 3-1). These species were chosen because they are resident in neighbouring streams and they were considered the most likely to be present in the C4 Stream. Therefore, these species are the most likely to be impacted by developments associated with the C4 Growth Cell.

3.4.1 Longfin and shortfin eels

Longfin and shortfin eels must migrate between marine and freshwater environments to complete their lifecycle. For these species, adult development and growth occurs in freshwater, and once maturity is reached they migrate downstream, through estuaries and into the marine environment. Reproduction is thought to occur somewhere in the Western Pacific Ocean. The larvae are then transported back to New Zealand on ocean currents. In the Waikato River, glass eels enter from July through to December (Jellyman et al. 2009). Longfin and shortfin eels transition into a pigmented juvenile eel (called an elver) and are on average one year-old once they reach the dam at Karapiro (Martin and Bowman, 2016). Once suitable habitat has been located, both species typically reside in the vicinity until maturity which can take over a decade.

The key factors known to influence the downstream migration of eels are increases in water level and flow associated with rainfall, and lunar periodicity, with maximum activity just before the last quarter (Todd 1981). However, rainfall and flow have been shown to be the best predictors of eel migrations (Boubée et al. 2001). Both longfin and shortfin eels have been recorded in the C4 Stream and are using this as rearing habitat until sexual maturity is reached. Therefore, maintaining a flashy or elevated flow regime in the stream will be important for stimulating the downstream migration of adult eels.

Shortfin and longfin elvers are skilled climbers, longfins reputedly more-so than shortfins (McDowall 2000). Elvers climb by attaching themselves to the substrate using friction and surface tension and undulating their bodies in an anguilliform motion as when swimming, but with their bodies in continuous contact with the substrate (Jellyman 1977). They often take advantage of rough substrate by wiggling between raised areas to provide greater surface area for adhesion. However, their ability to climb vertical surfaces is largely limited to when they are < 120 mm (Jellyman 1977; Jellyman et al. 2017). Based on their adept climbing abilities the culvert under Matos Segedin Drive is not considered a barrier for either eel species, however, the culvert under Cambridge Road requires further assessment.

3.4.2 Galaxiid species (giant kōkopu, banded kōkopu and īnanga)

Īnanga, banded kōkopu and giant kōkopu are typically considered diadromous as both marine and freshwater environments are used to complete their lifecycle. Banded and giant kōkopu generally spawn within the streams they reside in, whilst adult īnanga migrate down to the estuary to spawn. Larval dispersal and development occur in the marine environment, followed by inward migration of juveniles (whitebait) to freshwater where most feeding and growth occurs (McDowall 1990). Recent research from the Waikato River shows there is considerable flexibility in the life history of īnanga, banded kōkopu and giant kōkopu with many populations completing their lifecycle in freshwater (David et al. 2019) i.e., they have facultative diadromy. In the Waikato River Catchment, a high proportion of banded kōkopu and giant kōkopu residing in tributaries upstream of Huntly are non-diadromous meaning their entire life (including their larval life) was completed in freshwater.

Furthermore, David et al. (2019) identified the first population of non-migratory īnanga collected from a river within New Zealand (several lake populations of īnanga are known to exist, and in Chile many riverine *G. maculatus* are non-diadromous). These results suggest that in the Waikato River catchment, galaxiids with diadromous and non-diadromous life-history types need to be accounted and provided for in the restoration and protection of their habitats.

Giant kōkopu spawning occurs within rivers and streams during elevated flows following rainfall events. Spawning has only been recorded from two sites in Aotearoa-NZ, an urban stream in Hamilton and the Awaawaroa Wetland on Waiheke Island. Spawning is known to occur from late April to late June, but it possibly extends later (Franklin et al. 2015). Little is known about their spawning habits with most information to date coming from studies on a single population in the Waikato Region (Franklin et al. 2015). Currently, the known spawning vegetation is *Tradescantia fluminensis* (wandering willie), an invasive perennial herb; and *Carex germinata* but it is highly likely that giant kōkopu use other species of native and exotic grasses, sedges and rushes for spawning (Franklin et al. 2015).



Figure 3-9: Giant kōkopu (*Galaxias argenteus*) are one of the large-bodied Galaxiids found in the wider area.

Banded kōkopu (Figure 3-10) also spawn along bankside margins during elevated flows (Charteris et al. 2003) but can be quite variable in the selection of their spawning sites/habitats. Spawning sites for banded kōkopu include a mixture of small vegetation, gravel and woody debris (Charteris et al. 2003). Few spawning sites are known for banded kōkopu, but a site was recently identified in a tributary of the Waikato River (see Figure 3-11).

Both giant and banded kōkopu typically prefer low velocity pool habitats and do not have a preference for a particular substrate type. Their preference for very low velocity water may be related to their feeding habits, as both species sit at the water surface feeding on terrestrial insects that get trapped at the air/water interface (West et al. 2005). The surface waves produced by the struggling insect allows the kōkopu species to compute the direction and distance of their prey via their lateral line system (Halstead 1995). Both species are considered climbing galaxiids but banded kōkopu can overcome significant instream structures (e.g., waterfalls), whereas giant kōkopu have limited climbing abilities (McDowall 2000).



Figure 3-10: Banded kōkopu (*Galaxias fasciatus*) are one of the large-bodied Galaxiids found in the wider area.



Figure 3-11: Banded kōkopu spawning habitat (red circle) identified in 2018 in a tributary of the Waikato River near Hamilton.

The life histories and migrations of īnanga (Figure 3-12) are the most widely understood of the galaxiid species. For diadromous populations of īnanga, mature adults (50–125 mm in length) move downstream to their spawning sites (McDowall 1990), while non-diadromous populations are thought to move upstream to spawn. For īnanga that are diadromous, spawning occurs on riparian vegetation where the salt water wedge penetrates freshwaters at high tides (McDowall 1990). Spawning is linked to lunar and tidal cycles with most spawning occurring on spring-tide events. The spawning habitats of non-diadromous īnanga are unknown but it has been suggested that īnanga do not need a tidal cue to reproduce and can instead reproduce on elevated flows (Rowe and Kelly, 2009).



Figure 3-12: Īnanga (*Galaxias maculatus*) is the most widely distributed galaxiid in New Zealand and is found in the wider area of the C4 Stream.

Īnanga reproduce over an extensive period, from January in the south of New Zealand through to July in the north, with peripheral spawning also found outside of these 'peak' spawning times (Mitchell 1991, Taylor 2002). The eggs are typically deposited 10–15 cm above the highwater mark, take 2–4 weeks to develop and require humid conditions for successful development (Hickford and Schiel 2011). Īnanga have no climbing ability and must burst swim past instream obstacles.

3.4.3 Black mudfish

The black mudfish is an endemic wetland specialist but through habitat loss, pollution and sedimentation it is thought to now occupy less than 10% of its former range. Black mudfish are a particularly hardy species that can occupy waters with a wide range of pH (4–7), dissolved oxygen (as low as 0.3–1.8 mg/L; McPhail 1999) and water temperatures (up to 26°C; Thompson 1987). They can occupy ephemeral habitats by burying themselves in the sediment when it is dry and can remain dormant until surface water returns and they can re-emerge. As such, they have been known to occupy stormwater treatment wetlands where the environmental conditions may exclude less tolerant species (pers. comm. Bruno David, WRC). Mudfish are non-migratory and so passage to and from the Waikato River is not necessary.



Figure 3-13: Black mudfish (*Neochanna diversus*) are a declining species that found in the wider study area.

3.4.4 Common smelt

Common smelt (*Retropinna retropinna*; Figure 3-14) are widely spread throughout New Zealand. In the Waikato River catchment, Booker (2000) identified: (1) Non-diadromous populations (associated with lakes, e.g., Lake Taupō) and (2) diadromous populations. Booker (2000) found that the prevalence of diadromous and non-diadromous life histories was associated with changes in habitat structure and water quality. Differences include the number of gill rakers and vertebrae, size at maturity, maximum length and weight, fecundity, and relative density — as well as behavioural differences such as spawning period exist between diadromous and non-diadromous populations.



Figure 3-14: Common smelt (*Retropinna retropinna*).

Smelt are considered good swimmers and will penetrate well inland into river systems that are not too steep (e.g., the Whanganui and Manawātū Rivers). They are particularly abundant in the Waikato River catchment. They can reach 165 mm, but more commonly do not exceed 120 mm. This species can live up to four years of age, maturing at one year with an average generation time of 1.5 years. The main elements of this riverine life cycle are duplicated in lake-dwelling smelt populations (Ward et al. 2005). Spawning takes place annually in shallow, sandy margins of lakes and sandy river banks; however, lake and riverine populations spawn at different times of the year. Smelt are very sensitive to changes in their physical environment and are one of the most sensitive native fish species in New Zealand (Rowe et al. 2002; Rowe and Kusabs 2007).

Common smelt is a diadromous species that usually spends most of its life at sea, with mature adults returning to fresh water to breed. However, this is not the case for the Waikato River. Similar to the large galaxiid species, larvae hatch in fresh water and migrate out to sea where they feed and grow before returning to freshwater as juveniles for growth to adulthood (McDowall 2010). Once mature, adult smelt will migrate downstream and spawn in the lower reaches of the Waikato River mainstem, below Ngaruawahia (Baker & Bartels. 2011). In lake systems, these fish can choose to spawn within the lake and rear completely within freshwater.

3.4.5 Common bully

The common bully is widely found throughout New Zealand and is often observed in gently flowing streams and along the edges of lakes. Many of the people familiar with this species misname it as a “cockabully” (cockabullies are of a different family and are marine or estuarine fish). The common bully grows to about 150 mm in length, though adult fish are mostly less than 120 mm (Figure 3-15). Common bullies are considered a diadromous species, with juveniles moving out of the sea and moving upstream into rivers and lakes to grow and mature (McDowall 1990). Landlocked stocks are also common, and in some cases have probably been established by transfer from other waters. Populations in lake and lake tributaries are most likely non-diadromous and in the lower reaches of rivers they are mostly migratory (Hicks et al. 2017).



Figure 3-15: Common bully (*Gobiomorphus cotidianus*).

3.5 Hydrological, physical and ecological characteristics

The hydrological characteristics and flow duration curves for the upper and lower reaches in the C4 stream were almost identical (Table 3-2Error! Reference source not found.; Figure 3-16). At mean flows, the discharge at both reaches ranges between $0.09 - 0.11 \text{ m}^3 \text{ s}^{-1}$ for 50% of the time (Figure 3-16).

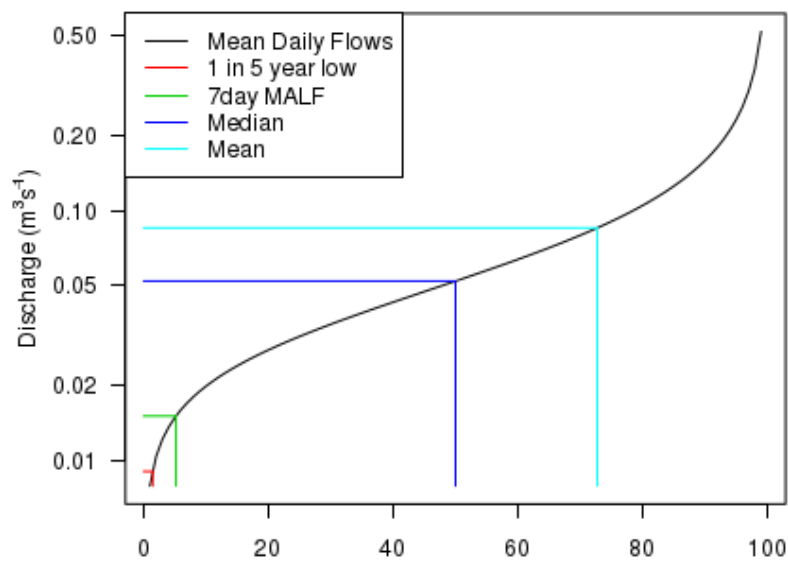
Table 3-2: The predicted hydrological characteristics for reaches in the C4 Stream above (upper) and below (lower) the proposed C4 Growth Cell development. Predictions are derived from the NZ River Maps tool. See Table A 1 for explanation of hydrological characteristics.

Hydrological characteristics	Reach	Flow (Litres/second) ²
1 in 5-year low flow	Upper	9.05
	Lower	12.2
Mean annual low flow	Upper	15.1
	Lower	20.2
Median flow	Upper	52.2
	Lower	71.9
Mean flow	Upper	85.2
	Lower	120
February flow seasonality	Upper	0.445
	Lower	0.434

² All measurements are in litres per second unless otherwise stated

Hydrological characteristics	Reach	Flow (Litres/second) ²
FRE3	Upper	11.7 events/yr ⁻¹
	Lower	12.3 events/yr ⁻¹
Month lowest mean flow	Upper	March
	Lower	March

a) Upper reach



b) Lower reach

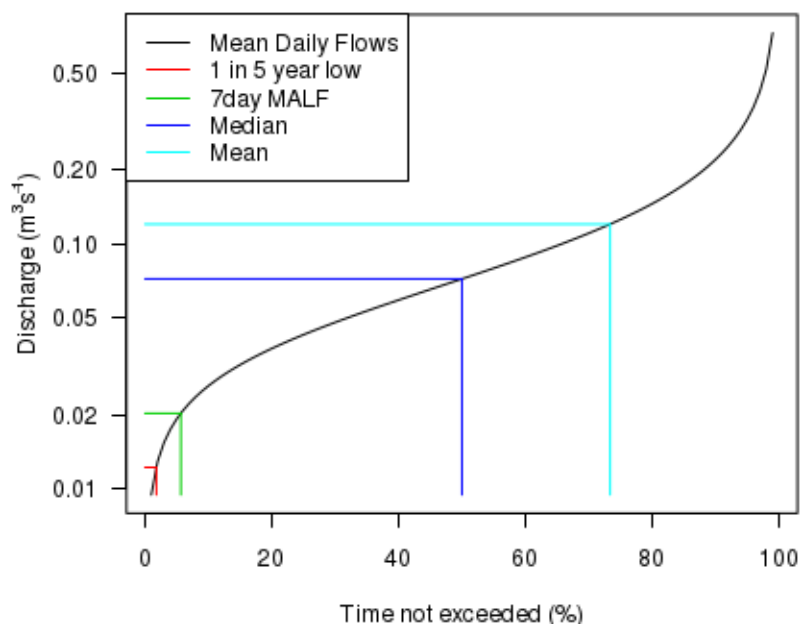


Figure 3-16: Predicted flow duration curves for five flow metrics in the upper and lower reaches of the C4 Stream. Predictions are derived from the New Zealand River Maps tool.

4 Discussion

From the site visit and synthesis of existing information, it was apparent that the habitats found in the upper reaches of the C4 Stream are likely capable of supporting black mudfish, banded kōkopu and giant kōkopu. The fallen trees and overhanging vegetation create cover and pool habitat that is preferred by banded kōkopu and giant kōkopu (Baker & Smith 2007), while ephemeral wetland habitats and seeps were identified which are the preferred habitats of black mudfish. In addition, habitats suitable for both eel species, īnanga, smelt and common bullies were also present. However, there are concerns about potential fish passage impediments in the C4 Stream that may be preventing these species from colonising the upper reaches (see section 4.1.3) and there are no records of these species in the C4 Stream from the NZFFD (although survey cover is minimal).

Longitudinal changes in the habitat quality of the C4 Stream were evident with the lower sites being the most degraded. Below Cambridge Road, the C4 Stream had poor riparian and canopy cover, evidence of stock damage and large sections of homogenous habitat. This lower habitat quality suggests that any impacts from the C4 Growth Cell Development and associated stormwater inputs will be greatest upstream of the lake where instream habitat diversity, stable banks and mature riparian buffer existed.

Overall the ecological integrity of the C4 Stream cannot be fully understood without an updated survey sampling the range of habitats present, including the lake, to determine the fish communities utilising the different habitat types.

4.1 Potential issues and constraints

4.1.1 Hydrological modifications from stormwater inputs

It is likely that the proposed C4 Growth Cell development may alter the hydrological regime of the C4 Stream. However, the magnitude of any hydrological modifications and their subsequent effects are unknown as the stormwater management plan has not been developed. No known hydrological data exists for the C4 Stream and changes in the mean annual low flow (MALF) and the magnitude and duration of peak flows from stormwater discharges cannot be examined currently.

To understand the hydrological alteration of rivers from discharges (i.e., stormwater) and subsequent effects on freshwater fish, several hydrological statistics are needed. For native freshwater fish, the flow regime of rivers is important for reproduction, movement and migration all of which may be restricted to a few months of the year (McDowall 1995) and linked to the occurrence of suitable flow conditions. For example, for kōkopu species, flood flows are important for successful spawning and larval hatching in the winter months (Charteris et al. 2003; Franklin et al. 2014). Fish migration, such as the downstream migration of sexually mature eels, is cued by flow variability (Todd 1981). Therefore, low flows may affect resident fish populations by restricting upstream movement for spawning. Furthermore, in many river systems, periods of higher flows are also necessary to prevent the accumulation of periphyton and fine sediment in low velocity areas (Snelder et al. 2014) that affect fish habitat quality.

Erosion because of stormwater discharges could change the morphology of the upper site and make it more incised. The C4 Stream may be able to support increased discharges from stormwater inputs given the wide flood plain that exists. Furthermore, within the wider ecological landscape, the riparian buffer that exist in the upper sections of the C4 Stream is more established and provides increased bank stability. However, there appear to be issues with hydrological connectivity at the

culvert under Cambridge Road and so increased stormwater discharges may result in flooding of the surrounding land above Cambridge Road (see section 4.1.3). Therefore, it is important that hydrological connectivity is facilitated and effectively maintained through the Cambridge Road culvert.

4.1.2 Contaminants

Contaminants associated with urban development can impact native fish ecology. Several key effects have been shown to occur even at low levels. For example, fish have their sensory systems in direct contact with the water and a variety of heavy metals (copper, cadmium, zinc, mercury, chromium and arsenic) have been shown to block sense of smell and taste in a wide variety of fish species (Klaprat et al. 1992). These heavy metals are common in domestic and industrial wastes. Baker and Montgomery (2001) found 0.5 and 2 µg/l Cd⁺² was capable of impairing olfactory and lateral line function respectively, in migratory banded kōkopu whitebait. As many native fish present in the Waikato River are diadromous, the loss of sensory systems such as smell (olfaction) could affect habitat selection and successful recruitment by migratory juveniles. For resident fish, a loss of olfaction could result in changes to predator/prey interactions and feeding behaviour. Furthermore, heavy metals (copper, zinc and lead) are known to impact on īnanga egg development and survival (Barbee et al. 2016). īnanga eggs exposed to these contaminants produce poorer quality larvae with reduced behavioural responses to light and poorer swimming abilities (Barbee et al. 2016). Thomas et al (2016) also showed that copper affects īnanga swimming ability and avoidance of stressors.

In general, fish species will not avoid low levels of contaminants. Richardson et al. (2001) examined the response of native fish such as īnanga, smelt and common bullies to copper (0.05 g/m³), low dissolved oxygen (c. 2 g/m³), and high and low ammonia (c. 8.5 and 2 g/m³ NH₃ respectively). Only smelt showed a strong avoidance to all pollutants. īnanga and common bullies did not avoid any contaminant except copper. Smelt have been promoted as an appropriate native species for establishing guidelines for New Zealand waterways (Rowe & Kusabs 2007) and usually their presence indicates that the water quality is suitable for most other fish. It is important that the stormwater management plan minimises additional contaminant inputs into the C4 Stream.

4.1.3 Assessment and remediation of fish passage structures

Two culverts were identified in the C4 Stream and there is a concern about whether the one under Cambridge Road is surmountable by fish, especially considering only two species with good climbing abilities (longfin eel and shortfin eel) have previously been identified in the upper section of the C4 Stream.

The removal of structures that impede fish passage is the primary and preferred solution (Franklin et al. 2018). Alternatively, replacement with a structure that has been designed to meet minimum design standards will likely offer the most sustainable and effective solution. For practical reasons many structures cannot be removed, so the addition of new features to existing structures is a more common strategy for enhancing fish passage. The remediation options available at a site will be dependent on factors including the characteristics of the existing structure, cost, accessibility, the reason(s) for reduced fish passage, and the ecological objectives for the site.

Alternatively, native fish species can benefit from natural or built barriers, and in some situations a selective barrier that provides access for climbing species over a natural or built barrier (e.g., banded and giant kōkopu), while preventing other non-climbing species (e.g., trout, rudd, koi carp) from moving upstream could be advantageous. For example, waterfalls maintain good native fish refuge

from introduced species. By preventing invasive fish access, these selective barriers provide access for young native fish to protected upstream habitats and protect spawning habitats of adult fish. Furthermore, there is a seemingly high proportion of galaxiid species found in the Waikato River catchment that do not migrate to sea to complete their life cycle. This means that self-sustaining populations can be established within the Waikato River catchment and these species may benefit from a selective barrier. The lake that exists in the C4 Stream may provide ideal habitat for larval fish as for many species it is thought that if a lentic habitat such as a lake exists downstream, the larvae will not migrate to sea and instead will rear within the system.

Therefore, the lake in the C4 Stream may provide an opportunity for developing lacustrine populations of native fish species such as banded and giant kokopu, smelt and common bullies. In this regard, to complement the fish surveys, the Cambridge Road culvert requires further assessment to determine what remediation, if any, is necessary.

4.2 Future recommendations

- We recommend an ecological survey be undertaken in summer to describe the habitats and freshwater fish community in the C4 Stream. This would include a survey of the upper and lower sections of the stream and the lake. In addition, we recommend carrying out macroinvertebrate surveys in perennial stream sections.
- We recommend an assessment of the culvert under Cambridge Road. It is not clear if this structure is facilitating fish passage as species with poorer swimming and climbing abilities (such as īnanga and giant kōkopu, respectively), have not been recorded in the C4 Stream and their passage may be impeded by the culvert. The fish survey will also help determine the level of impediment this structure presents to fish passage.
- If possible, an ecological flow assessment using RHYHABSIM or similar physical habitat model is recommended to enable habitat changes with an altered flow regime to be more accurately assessed.

5 Acknowledgements

Thanks to Amber Sinton for producing the maps of freshwater fish species distributions from the New Zealand Freshwater Fish Database. We thank the landowners for access to land to complete the site visit.

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Appendix A

Table A-1: Flow statistics and their calculations for the C4 Stream. These statistics are derived from the New Zealand River Maps tool.

Hydrological characteristic Ls^{-1}	Meaning
1 in 5-year low flow	One in 5-year low flow on average over all time after having applied a 7-day running average and assuming that annual low flows take a normal distribution ($m^3 s^{-1}$). Lower values mean less flow.
Mean annual low flow (MALF)	The mean of the annual low flow series after having applied a 7-day running average ($m^3 s^{-1}$). Lower values mean less flow.
Median flow	The predicted median of mean daily flow time-series over all time ($m^3 s^{-1}$). Lower values mean less flow.
Mean flow	Mean flow over all time ($m^3 s^{-1}$). Lower values mean less flow.
February flow seasonality	Mean flow in February divided by mean flow over all time. Provides an estimate of flow seasonality. Values lower than 1 indicates mean flow in February is less than overall mean flow.
FRE3 (events per year)	The average number of events per year that exceed three times the median flow (events/year). Calculated from mean daily flows with no windows applied to account for peaks that occur in quick succession. Provides an estimate of flow flashiness. Lower values mean less frequent events.
Month lowest mean flow	The month with the lowest mean flow