MORPHUM ENVIRONMENTAL LTD

Engineers & Consultants

Watercourse Assessment Report

Ngakoroa Catchment

Final

Prepared for Auckland Council by Morphum Environmental Ltd

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Executive Summary

Morphum Environmental Ltd was engaged by Auckland Council to undertake a detailed assessment of the watercourses within the Ngakoroa catchment. The watercourse assessments were conducted between January and April 2018, in accord with the Watercourse Assessment Methodology: Infrastructure and Ecology version 2.0. Overall, over 89 km of watercourse was assessed, including 675 stormwater assets, pipes and culverts, and 457 wetlands (see Table 1). Five Stream Ecological Valuation assessments (SEV's) were also conducted at representative locations across the catchment.

Watercourse Assessment Reports (previously called Watercourse Management Plans and Streamwalk Reports) provide baseline information on the existing condition of rural and urban waterways. This includes the assessment of both infrastructure e.g. pipe outfalls and environmental components e.g. stream state. Watercourse Assessment Reports aim to provide information that can be used to maintain high value streams and enhance degraded streams while recognising the future growth pressures facing the Auckland Region. The outputs are used by Council as key resource in the management of waterways. They serve to support achieving multiple objectives within realistic environmental, economic and social constraints and inform the effective management of:

- Stream ecological health (e.g. degraded habitats);
- Stormwater infrastructure (e.g. eroded pipes); and,
- Stormwater conveyance (e.g. flooding).
- Land-use planning (e.g. riparian esplanade definition)

Key knowledge gaps that are supported by this Watercourse Assessment include:

- Documentation on the state of riparian corridors
- Identification of forest fragments not previously recorded
- Records of native fish distribution
- Location, and extent of remaining wetlands.
- Updated delineation of watercourses

A literature review of local-scale historical reports is summarised in Section 2 of this report, while Management Zones and recommendations are described in Section 3. These are supported by a more detailed summary of results from the watercourse assessment, and Stream Ecological Valuations (SEV's) in Sections 4 and 5 respectively. Specific Enhancement Opportunities are described in Section 6.

The Ngakoroa catchment encompasses a total area of 40.15 km^2 and extends northwards from the Bombay Hills towards Drury. The catchment is primarily drained by the Ngakoroa Stream, which discharges to Drury Creek and then to the Pahurehure Inlet of the Manukau Harbour. The Ngakoroa Stream also includes a large tributary, designated as Ngakoroa West, which splits from the main branch in the Runciman area and extends south west for approximately one-third of the catchment length.

A small sub-catchment draining directly to the Pahurehure Inlet is also present to the west of Drury, referred to as Pahurehure Inlet Tributary in this report.

Due to the gentle topography of the area, freshwater systems tend to be low order, low energy watercourses connected to large wetland areas. These waterways serve vital drainage and flood protection functions throughout this landscape.

The entire Ngakoroa catchment is rural, with land-use being predominantly made up of residential lifestyle blocks and pastoral grazing land to the north, with large areas of market gardening to the west

and south. This catchment contains some of the most productive soils in the country, which are highly valued for vegetable production and short rotation crops.

The initial and approved future urban development is in the northernmost part and extends to the sub-catchments to the east and west. Subsequent phases of development will primarily occur within the Future Urban Zone (FUZ), which is centred around Runciman in the northern portion of the catchment.

This FUZ, designated Drury West, encompasses approximately 1000 ha in total and will be subject to intensive development of residential subdivisions. Approximately 11,250 dwellings are planned to be constructed in this area in stages until 2032.

Overall the catchment is highly modified, with historical vegetation clearance resulting in only small, fragmented pockets of native vegetation remaining. Modified stream channels are evident throughout the catchment, with the most common form of modification being straightening to increase conveyance. Modified channels are more common within market gardening areas, as well as the FUZ where a number of the lower reaches of the Ngakoroa West tributary have been straightened as part of historical wetland drainage.

In general the streams within the Ngakoroa catchment are soft-bottomed and highly homogenous, with flow regimes mainly consisting of runs with some pools. Only 5% of reaches have more than three habitat types present, indicating that in-stream habitat structure suitable for a variety of aquatic fauna and flora is largely lacking at a catchment scale.

There is an overall lack of stable in-stream habitat components, such as boulders or large woody debris, throughout the catchment and, together with the rarity of low-gradient banks with deep leaf litter and high overhead cover, results in a lack of spawning habitat for native fish species.

One of the main issues identified was the high level of deposited loose sediment present along many of the stream reaches. In some places this loose sediment reached 0.7 m in depth and smothered the stream bed completely.

Although 58% of the stream length surveyed was assessed as having either fair or poor stability, bank erosion did not emerge as a major issue within this catchment as only 5% of the stream length surveyed had erosion levels greater than 40%. Given the level of sedimentation observed, the source of the sediment is therefore is more likely attributable to land-use effects, including runoff from pastoral landscapes, and also soil loss and erosion from exposed soil surfaces in horticultural areas.

Less than 20% of the catchment has riparian buffer widths exceeding 15 m. This represents a significant opportunity to increase indigenous biodiversity values by improving the amount of riparian coverage along streams.

This general lack of riparian shading, along with large amounts of loose sediment, meant that the excessive growth of emergent weedy macrophytes, such as water celery and willow weed, was common along many reaches.

Online ponds and dams were widespread throughout the catchment, with the Ngakoroa West tributary containing a high proportion of these. Of particular note are two large dams on this tributary, the larger of which is 4 ha in size and the smaller 1.1 ha. Both of these dams contain large surface-reaching beds of the aquatic weed *Egeria densa*. Online dams and ponds contribute to negative environmental impacts within the catchment, such as their outlets presenting potential barriers to fish passage; reduced dissolved oxygen levels due to excessive aquatic weed growth; thermal stratification and discharge of

higher temperature water; increased flooding risk to downstream properties; and the provision of ideal habitat for pest plants and fish to colonise.

The near ubiquitous presence of the invasive mosquitofish (*Gambusia affinis*) throughout the catchment is largely due to its ability to thrive in shallow, highly-modified watercourses. The high number of artificial ponds and macrophyte-clogged streams present throughout the Ngakoroa catchment provide habitats that are much better suited to this species than to most native fish, which prefer streams with high riparian cover and lower water temperatures.

Artificial barriers to the upstream migration of native fish species were largely lacking from the main stem of the Ngakoroa Stream, with the first barrier being a Council-owned hydrological monitoring weir located in the upper part of the catchment near Bombay. This means that native fish such as inanga, which are unable to climb past in-stream barriers, are likely to be able to utilise the full extent of their natural habitat within the main stem of the stream unencumbered by artificial barriers to fish passage.

The main barriers to fish passage on the main stem of the Ngakoroa Stream are caused by a series of natural waterfalls and cascades located in the mid-catchment area, which act as the upper limit of fish passage for swimming species and also act as natural impediments to the distribution of other native species as well.

The lack of artificial barriers on the main stem of the Ngakoroa Stream does not apply to the stream tributaries however, as these contain a large number of fish barriers, many of which are associated with the outflow structures from online ponds and culverts associated with farm crossings.

There is a notable lack of parks and public open space within the catchment, which will become more important with the onset of the planned residential development in the area. There is significant scope for the Ngakoroa Stream to be better utilised for its amenity value, with the creation of esplanade reserves to provide public open space for recreation and areas containing waterfalls and deep pools which are potential local picnic spots and swimming holes.

Overall, eight management zones have been identified for the Ngakoroa catchment based on reaches with similar pressures, issues, and enhancement drivers. A summary of possible management objectives for each management zone are outlined in Table 2 below.

Management actions have been outlined in this report to support the general outcomes sought by the Auckland Unitary Plan, the Drury Structure Plan and the Franklin Local Board including:

- Addressing the issue of large-scale soil loss and erosion of cultivated land, and the consequent sedimentation of receiving environments, including streams throughout the catchment and the Pahurehure Inlet of the Manukau Harbour;
- Preservation of all existing permanent and intermittent watercourses through avoidance of any further reclamation or diversion;
- Removal of online ponds to address the associated impacts on water quality and freshwater ecology;
- Protection and enhancement of ecological values, including the protection of existing areas of native vegetation, development of esplanade reserves, and the planting of riparian corridors to extend and connect existing Significant Ecological Areas;
- The creation of stormwater treatment wetlands to promote integrated, catchment-based stormwater quality and flood management measures;
- Stream restoration to improve diversity of habitat and hydrologic conditions, particularly where streams have been historically straightened/modified;

- Remediation of significant artificial barriers to fish passage;
- Enhancing the amenity values of the Ngakoroa Stream, especially where the presence of notable natural features such as large natural waterfalls and pools provide the opportunity for public recreational areas to be established;
- Addressing significant risks associated with engineered structures, such as scouring around the piles of a bridge on Runciman Rd (NGA_TRIB9_1) and a bridge on TRIB8b_1 that poses a flooding risk to non-habitable floors.

A total of 131 engineering assets throughout the catchment were identified as requiring some level of remedial action. Of these, 91 were inlet/outlet structures and 40 were pipes or culverts. The verified field data will also be beneficial for updating Auckland Council's stormwater GIS databases, with 224 inlet/outlet structures and 303 culverts or pipes located that were not otherwise recorded in GIS.

Seventeen specific enhancement opportunities have been identified to provide examples of tangible projects to support the Management Zone objectives, and to coordinate asset maintenance or repair actions where these are spatially clustered. Many of these enhancement opportunities involve the restoration of the hydrologic structure and form of streams and wetlands within the catchment, as well as the enhancement of connectivity between existing areas of native vegetation in order to reduce forest fragmentation and improve ecological values on a landscape scale.

While the streams within the Ngakoroa catchment are likely to be affected by the planned changes in land-use and extensive residential development associated with this, the processes around the granting of resource consents provide mechanisms by which the protection and enhancement of these sensitive environments can be prioritised in order to achieve a net environmental benefit.

Table 1: Summary of Ngakoroa Catchment						
Total Length of Surveyed Watercourse (m)	**89,946**					
Catchment Area (km²)	40.15					
Catchment Imperviousness	0.5%					
Receiving Environment	Pahurehure Inlet, Manukau Harbour					
Dominant Substrate	Silt/Sand					
Vegetation	**0 – 10 %**	**10-30%**	**30-50%**	**50-70%**	**70-90%**	**>90%**
Average Overhead Cover (% of total stream length)	31.2	18.5	14.1	18	13.3	4.8
Wetlands	**Natural**			**Artificial**		
Number of Wetlands	200			257		
Erosion	**Excellent**	**Good**		**Fair**		**Poor**
Overall Stability Index (% of total stream length)	7	34		27		31
	Percentage of reaches with >60% erosion scarring			**Total no. erosion hotspots**		
	0.8%			25		
Engineered Assets	**Total No.**	**Poor-Very Poor Condition**		**Incorrect in GIS**		**Accessible Unsafe Drops >1.5m**
Inlet and Outlet Structures	277	17		1		14
Pipes and Culverts	398	16		0		N/A
Bank and Channel Lining (total length (m))	144	4		N/A		70
Fish	**No. of species observed**	**Percentage of fish points with suitable habitat**		**Percentage of reaches with suitable habitat**		
	8	11		12		
Potential Barriers to Fish Passage	**Swimmers**	**Climbers**		**Anguilliformes**		
Natural Structures	50	7		3		
Inlets and Outlet Structures	0	12		2		
Pipes and Culverts	0	105		55		

Table 2: Summary of Management Zones and Objectives

Management Zones	Stream Naturalisation	Online Pond Remediation	Water quality treatment	Fish Passage Remediation	Erosion Remediation	Water sensitive Communities	Fencing	Riparian vegetation enhancement	Weed Control	Inanga Spawning	Industrial Pollution Control and Compliance	Infrastructure Remediation
MZ1	✓				✓			✓	✓	✓		
MZ2	✓	✓		✓			✓	✓				✓
MZ3					✓	✓						✓
MZ4			✓		✓		✓	✓				
MZ5					✓		✓	✓	✓			
MZ6		✓		✓	✓		✓	✓			✓	✓
MZ7								✓	✓			
MZ8								✓	✓			✓

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Figures

Tables

1.0 Introduction

The objective of this project was to undertake a Watercourse Assessment and prepare a Watercourse Assessment Report (WAR) and geodatabase that will provide a framework for prioritised management of the watercourses in the Ngakoroa catchment, particularly the areas noted for Future Urban development.

It should be noted that the name of the stream has been spelt as 'Ngakaroa' in a number of Auckland Council publications, however the official name of the stream according to Land Information New Zealand is 'Ngakoroa'. This spelling is therefore used throughout this report.

The scope of this project is described as follows and detailed in Table 3:

- Undertake a Watercourse Assessment and prepare a Watercourse Assessment Report (WAR) for the Ngakoroa catchment, including associated maps and completed geodatabase.
- All services must be undertaken in accordance with the Watercourse Assessment Methodology: Infrastructure and Ecology Document (Version 2.0).
- The length of stream identified within the scoping map must be surveyed.
- Five Stream Ecological Valuations (SEVs) are to be undertaken within the catchment. The location of the SEV's was selected in consultation with Auckland Council and following Appendix B Ancillary in the Watercourse Assessment Methodology.

The stream survey was conducted in accordance with the Watercourse Assessment Methodology: Infrastructure and Ecology (Version 2.0) which replaces the former Auckland Council Specification for Stream Assessment Surveys and Watercourse Management Plans.

Table 3: Watercourse Assessment scope matrix

Watercourse Management Plan Component Protocol	Ngakoroa Catchment
Pre-survey Desktop Assessment	Yes
Literature Review	Yes
Field Stream Assessment	Yes
Reach Assessment (Ecoline)	Yes
Natural Structures	Yes
Fish Survey	Yes
Stream Mouths	Yes
Inanga Spawning	Yes
Wetlands	Yes
Asset Inspection (Inlets/Outlets)	Yes
Asset Inspection (Culverts/ Pipes)	Yes
Bank and Channel Lining	Yes
Erosion Hotspots	Yes
Enhancement Opportunities	Yes
Miscellaneous Points	Yes
Post-survey Desktop Assessment	Yes
Management Zones	Yes
Stream Ecological Valuations (SEVS)	Yes
Electrofishing	Yes
Clarity Measurements	Yes
Sediment Chemistry and *E. Coli*	Yes

1.1 How to use this document

1.1.1 Overview

The Watercourse Assessment Report document summarises comprehensive data collected during the field watercourse assessment, as well as, additional Stream Ecological Valuations (SEV's) conducted at representative reaches throughout the survey area. The document relies on tables and maps to provide concise information to guide selection of management actions.

This document consists of a literature review (Section 2.0), watercourse management (Section 3.0), summary of the watercourse assessment findings (Section 4.0), SEV results (Section 5.0), and Enhancement Opportunities (Section 6.0).

These sections are supported by a Map Series provided in the appendices, which should be referred to whilst reading the body of the Watercourse Assessment Report. These maps include:

- Map 1: Catchment Overview – extent of permanent, intermittent and ephemeral watercourses; tributary codes.
- Map 2: Catchment Land-use – Auckland Unitary Plan zoning.
- Map 3: Bank and Channel Modifications – channel lining; stormwater infrastructure.
- Map 4: Asset Maintenance Issues – extent of bank erosion scars; issues with engineered inlets/outlets; bank stability; issues with pipes/culverts; location of erosion hotspots; location of miscellaneous points.
- Map 5: Riparian Vegetation – level of overhead shading; notable trees; weed infestations; significant vegetation/trees; location of Council and QEII Trust covenants; location of Significant Ecological Areas; location of natural and artificial wetlands.
- Map 6: Inanga and Fish incl. Misc Data – fish survey records; records from NZ Freshwater Fish Database; location of natural and engineering barriers to fish passage.
- Map 7: Management Zones – location of management zones; location of enhancement opportunities.

The geodatabase provided with this report should be used for further analysis and interrogation of data.

Refer to the Watercourse Assessment Methodology document (Lowe *et al.* 2014) for information regarding survey methodologies and data collected during the field survey as well as information on the background and objectives of the Watercourse Assessment process and relevant policies and plans. Figure 1 provides a guide to the Watercourse Assessment structure.

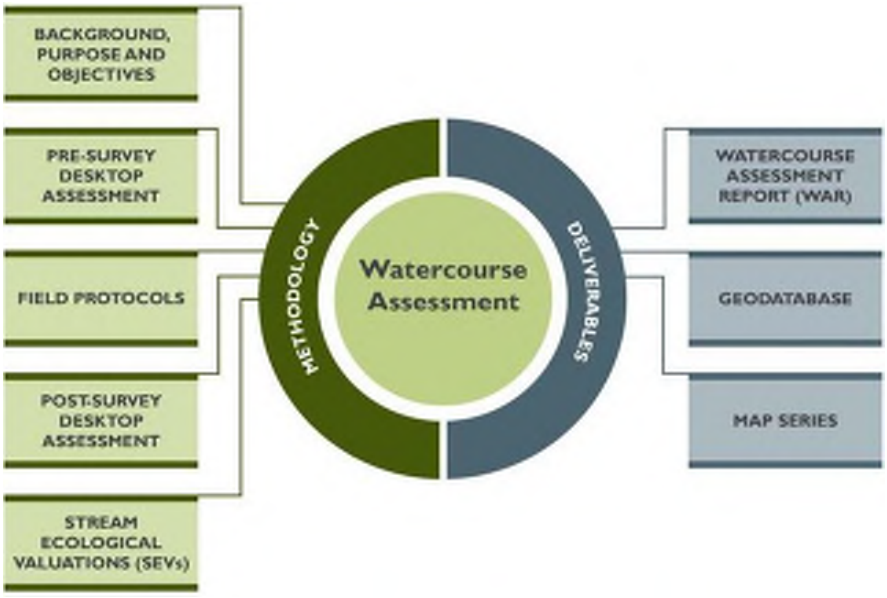


Figure 1: Watercourse Assessment structure

1.1.2 Limitations

Only streams that were within the scope of works for this project were surveyed. The methodologies implemented and the scope are such that there is potential that some streams may have been missed and that only portions of other streams were assessed.

1.1.3 Identified Options

Auckland Council is not obligated to undertake any works identified as enhancement or management options in a WAR, nor is Auckland Council bound by preliminary prioritisation of projects undertaken as part of this methodology. The recommendations made are to be considered within the context of Auckland Council's obligations, constraints, drivers, project identification, and catchment prioritisation undertaken or identified by Auckland Council.

1.1.4 Stream Classification

The Watercourse Assessment provides an unofficial field estimate of stream classification only and this classification is not specifically intended for Resource Consent purposes. Although specific and detailed assessment is required prior to consent approval for any works within a subject reach, the details contained in this document can be used to guide associated investigations for a resource consent application. Failure to identify a stream reach during this Watercourse Assessment process does not suggest that a stream does not exist or that any such stream is ephemeral.

1.1.5 Temporal Limitations

Watercourse Assessment undertaken as per this methodology must be considered within the seasonal context. Variables such as water depth and velocity are dependent on the level of base flow and stormwater influx prior to the assessment. Time since last rainfall event is recorded, which can guide interpretation. Factors that are more variable over diurnal time scales, such as temperature, are not recorded as part of this assessment as time series data is required for meaningful results.

1.1.6 Rapid Assessment Methodology

It is acknowledged that the Watercourse Assessment Methodology is a rapid assessment of engineering assets, as well as biological and geomorphological stream state, for the purpose of informing effective management of stream ecological health, stormwater infrastructure and stormwater conveyance. Therefore this methodology may lack some parameters of more specific assessments (some of which have informed the development of this methodology).

2.0 Literature Review

2.1 Overview of existing management plans

2.1.1 Auckland Unitary Plan – Operative in Part

The Auckland Unitary Plan (AUP-OP, 2017) provides the primary regulatory framework to manage Auckland's natural and physical resources whilst enabling growth and development in the region. The Unitary Plan supersedes the previous Auckland Regional Policy Statement, Auckland Regional Plans, and Auckland Council District Plans and is the principal statutory planning document for Auckland. The Unitary Plan has also introduced interim guidelines for managing the adverse effects of activities on freshwater and coastal waters in accordance with the National Policy Statement for Freshwater Management. To this effect, discharges, subdivision, use, and development should be managed to maintain or enhance water quality where the existing condition is above the national bottom lines and Macroinvertebrate Community Index (MCI) guidelines, or to enhance water quality where the current condition is below these guidelines.

2.1.2 Future Urban Land Supply Strategy

The Auckland Future Urban Land Supply Strategy (2017) recognises the demand for and housing in the Auckland region and sequences future urban development land over the next 30 years. It has been updated to reflect recent changes to the Unitary Plan, new demand for development and further technical work undertaken by Council to gain a greater understanding of the requirements for development.

The area of development that overlaps with this study is in the Drury West area, which is planned for approximately 1000 hectares in total. Within this area, 87 ha has been master planned and rezoned and construction was currently underway for this development, known as Auranga.

A Structure Plan for Drury West has been prepared by Karaka and Drury Limited, the developers of the Auranga subdivision, to support a request for a Private Plan Change to rezone an area within the Future Urban Zone (FUZ) to support extensive residential subdivision.

Table 4: Summary of Land Development Strategy

Name	Size	Dwellings	Development ready
Drury West Live zone, Auranga	87 ha	1,350 dwellings	2017
Drury West Stage 1	392 ha	Approx. 4,200 dwellings	2022
Drury West Stage 2	552 ha	Approx. 5,700 dwellings	2032

Overall the Structure Plan assessed the freshwater ecology values within the Drury West area as being low to moderate. The heavy modification of all streams due to past farming activities, a lack of riparian cover, the presence of non-functional farm culverts, and stock access to stream were all identified as factors in the current degraded state of the waterways in the area.

Ecological enhancement opportunities identified in the Structure Plan are based around restoring riparian and esplanade linkages. Incorporating the existing network of streams and remaining small wetlands within the Drury West area to connect with new green open space, street trees, residential gardens and rain gardens that will be created as part of the new subdivisions is seen as a way to enhance habitats for local flora and fauna.

There are seven key urban design priorities define the Drury West Master Plan based on domestic and international authorities on urban design best practice (Drury West Structure Plan). Key priorities are:

- Maximise connections and frontage to the coastal edge
- Promote mixed and walkable neighbourhoods
- Deliver distinctive and memorable public experiences
- Define and coherently lay out public and private spaces
- Provide a legible and navigable urban structure
- Maximise potential densities and yields
- The ability for locals to meet their daily needs.

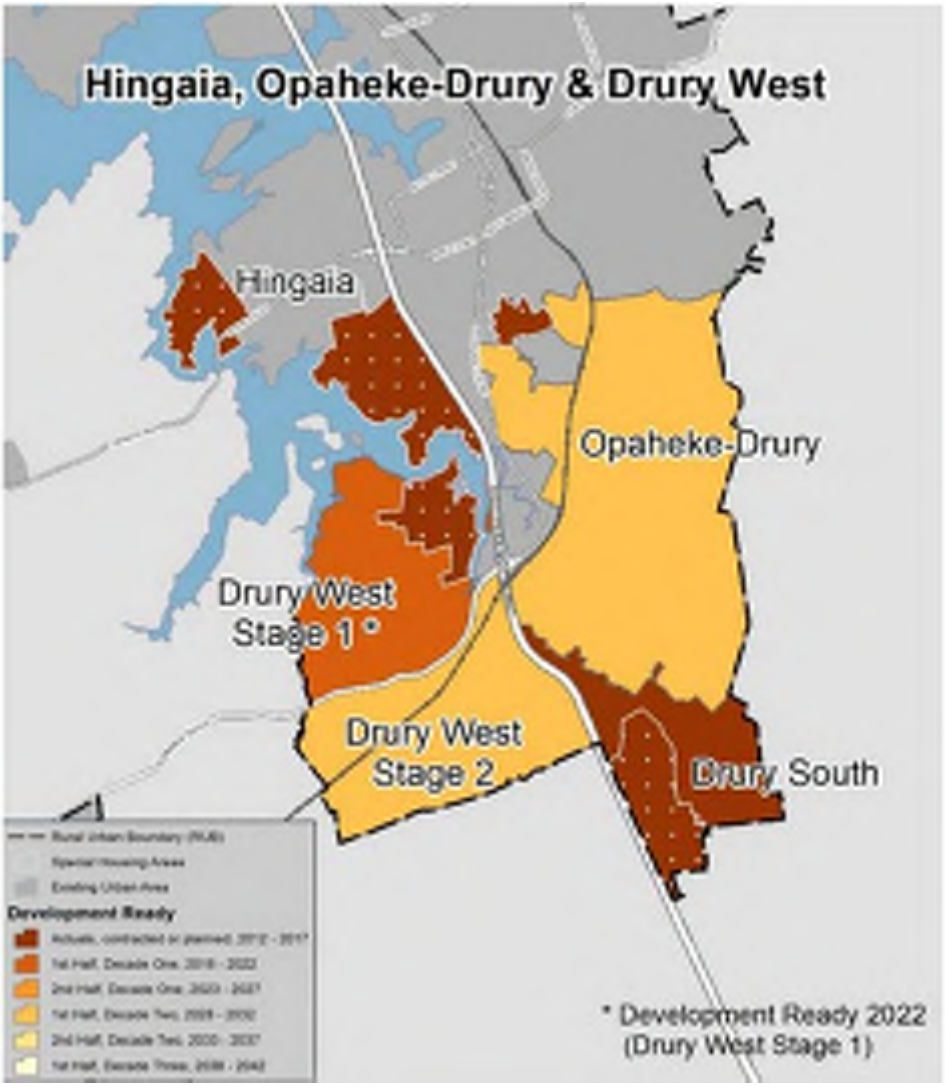


Figure 2: Drury - Future Urban Land Supply Strategy (Auckland Council 2017)

2.1.3 Precinct Plans

The Runciman Precinct lies within the Ngakoroa catchment immediately to the south of the Future Urban Zone. It is an area designated for the development of rural subdivision, and is zoned Rural – Countryside Living in the Auckland Unitary Plan.

Within this area are two sub-precincts, Sub-precinct A – Open and Sub-precinct B – Treed. These are largely differentiated by topography, with Sub-precinct A, being flatter and more open in aspect, while Sub-precinct B is characterised by rolling hills and with a greater amount of established vegetation.

Within the Ngakoroa catchment the two main blocks that form Sub-precinct A are located to the north and south of the Precinct area, with the area designated as Sub-precinct B located in-between (see Map 2; Appendix 1).

The objective of the Precinct Plan, which is contained within the larger Unitary Plan, is to accommodate countryside living subdivision in a way that retains an open and spacious rural character, acknowledges the landscape characteristics of the area, provides for the enhancement and restoration of the local environment, and ensures vehicle access and recreational trails for local residents.

2.1.4 Local Board Plans 2017

Drury West is wholly located within the Franklin Local Board area.

Specific aspirations of the Franklin Local Board Plan (2017) and initiatives relevant to Drury West include:

- To enhance, protect, and maintain our diverse natural environment and make sure it's able to be enjoyed.
  - Focus on improving water quality through working with local communities
  - Support good pest management practices through education and help local groups with pest control initiatives
- Growth is dealt with effectively
- Communities feel ownership and connection to their area.

2.2 Catchment Overview

There is no integrated catchment management plan for the catchment. The catchment is relatively narrow, extending north from the Bombay Hills to the Drury Creek which is part of the Manukau Harbour. The drainage network is limited to two river systems, the main one starting near Bombay and extending north through the length of the catchment to Drury Creek. Due to the gentle topography of the area, freshwater systems are low order, low energy watercourses connected to large wetland areas. The waterways serve vital drainage and flood protection functions in this landscape.

Due to development, the land cover has been transformed and the original species composition and ecological functioning has been lost or compromised over much of the catchment. Watercourses have largely remained in their natural alignment, but their value has been degraded by the removal of vegetation cover, increased sedimentation, nutrients from surrounding land use, and in some areas, channel modification and the draining of wetlands.

The catchment is largely composed of agriculture (horticulture and livestock) as well as lifestyle properties. The initial and approved future urban development is in the northern most part and extends to the catchments to the east and west. Subsequent phases of future urban zones are also all located in the northern portion of the catchment.

The catchment drains from the Pukekohe volcanic plateau and receives discharge from the volcanic aquifers in the central area – the Bombay Drury Kaawa Aquifer Area (30.2 km^2) and in the south of the catchment, the Bombay Volcanic Area (35.5 km^2), both of which are identified as High Use Aquifer Management Areas.

The underlying geology of the catchment is predominantly basalt lava flows surrounding a small scoria cone in the southern part of the catchment. The middle of the catchment is dominated by ash, lapilli and lithic tuff, with argillite chert spilite underlying the northern third of the catchment towards the coast.

The Ngakoroa catchment is also noted as a 'High Use Stream Management Area'. This means that the value of waterways in this catchment are threatened by high use or take by a number of users. The primary high use is expected to be water extraction for agricultural irrigation.

The catchment is not serviced by a formal waste water network, and most properties are likely to be on a septic tank system. Lockie and Neale (2012) reported *E. coli* levels within the Ngakoroa Stream (2100 per 100ml) exceeded recreational guideline limits (550 per 100ml) in 2011.

Due to the highly impacted nature of the original freshwater and terrestrial ecosystems, there is significant opportunity to restore functionality and ecosystem services through sound restoration practices.

Table 5: Ngakoroa Catchment Overview

Attribute							
Catchment Area (km^2)	40.15						
Geology	Alluvial and colluvial deposits, Ash; lapilli and lithic tuff, Basalt lava, Scoria						
% Imperviousness	0.5						
Land Use Type	**Public Open Space**	**Rural**	**Residential**	**Business**	**Special Purpose**	**General**	**New Growth**
Land use (% catchment)	1.5	72.6	2	0.25	5.3	4.8	13.6
Receiving Environment	Pahurehure Inlet, Manukau Harbour						

2.3 Catchment Development History

The Ngakoroa catchment includes extensive natural resources including large waterways, fertile, low lying cultivation areas, and proximity to the resources of the Manukau Harbour that would have made the area desirable for Maori settlement (Brown and Brown, 2017).

European settlement, and the alienation of Maori from the area, began in 1842. Thomas Runciman is identified as the first settler in the area, remembered in the name of the Runciman district, and road.

The Great South Rd was constructed in the 1860's extending as far as Drury. The extension of SH1 from Takanini to Runciman in 1965 increased the capacity of key transport corridors to the area.

Agricultural practices have dominated the area, serving the produce markets of Auckland. Market gardening was established around 1899, utilising the highly fertile, volcanic soils in the region. This is still the dominant land use activity in the catchment, providing the largest horticultural production area in Auckland.

Recent subdivision for residential housing has been undertaken in the vicinity of Bombay and Razorback Roads (2012-2014) within the footprint of former market gardens.

2.4 Prior Watercourse Assessments

RMA Ecology undertook an ecological assessment of the Auranga B1 development, an 82 ha area to the west of the existing Drury 1 Precinct that is proposed to be rezoned for residential housing. This ecological assessment was undertaken to support the Structure Plan proposed by the developers of Auranga; Karaka & Drury Limited, and included surveys of terrestrial, freshwater and coastal fringe habitats.

Approximately 4,330 m of waterways were identified, of which 57 m were piped. The majority of streams were assessed to be ephemeral or intermittent (1,621 m and 1,775 m respectively), with 936 m assessed as permanent.

In addition, 6,400 m^2 of ponds and a single 520 m^2 freshwater wetland were also found within this area.

Overall, aquatic ecology values within the Auranga B1 area were found to be low to moderate, with biological and water quality data showing that the streams in the area were degraded. The significant modification of streams through farming activities, including stock access to waterways and a lack of riparian cover, were

assessed as being the main issues affecting the ecological quality of freshwater environments within the Auranga area.

2.5 Auckland Council Environmental Monitoring

Auckland Council has two environmental monitoring sites within the Ngakoroa catchment. One of these is a flow monitoring weir located in the upper reaches of the Ngakoroa Stream near Mill Rd, Bombay, which also serves as a water quality and stream ecology monitoring site. The other site is a groundwater hydrology bore located at Cooper Rd in Ramarama.

Long-term monitoring shows declining trends in both forms of phosphorus, while turbidity, suspended solids and oxidised nitrate concentrations are increasing (Buckthought & Neale, 2016).

2.6 Other Ecological Surveys

As mentioned in Section 2.4, the ecological assessment of the Auranga B1 area by RMA Ecology included surveying terrestrial and coastal fringe habitats in addition to the freshwater environments. Assessment of these habitats concluded that, due to the small amount of native vegetation remaining and the highly modified nature of the structure plan area, the landscape currently provides little in the way of habitat or connective corridors for forest birds or many native terrestrial fauna in general.

2.7 Drury Structure Plan – Ecological Assessment

A summary of current ecological values was prepared for the Drury-Opaheke Structure Plan area, which includes the Ngakoroa catchment Future Urban Zone (Nathan, 2017).

Key findings of this report include:

- The ecological value and long term viability of remaining isolated forest fragments is severely compromised however many of these forest fragments are poorly documented or databased.
- Exotic shelterbelt plantings provide important refuge and connectivity across the landscape in the absence of other vegetation.
- Significant impacts on watercourses are typical throughout the area and associated with agricultural land use including elevated in stream temperatures, channelization and reduction in habitat diversity and quality, poor riparian vegetation and excessive macrophyte growth, proliferation of pest fish *Gambusia* (mosquitofish), instream structures limited fish passage and access to upper catchment area.

Key ecological opportunities and outcomes sought through the structure planning process include:

- Provide planting to complete gaps in ecological connectivity at a broad, landscape level focusing on movement between the Pahurehure Inlet to the Hunua foothills. (east to west)
- Utilise riparian corridors to achieve this goal seeking a minimum of 10 m riparian widths (excluding any recreational or transport space)
- Increase connectivity between remaining forest fragments
- Seek opportunities to re-establish wetland ecosystems particularly in floodplains where wetlands would have historically occurred.
- Remove online ponds through development
- Protection of remaining ecological values including existing vegetation, existing wetlands, and existing permanent and intermittent streams.
- Upgrade stormwater treatment in conjunction with road corridor upgrades

Key knowledge gaps identified that may be supported by this Watercourse Assessment include:

- Documentation on the state of riparian corridors
- Identification of forest fragments not previously recorded
- Records of native fish distribution

- Location, and extent of remaining wetlands.
- Updated delineation of watercourses

2.8 Significant and Existing Ecological Values

Terrestrial Significant Ecological Areas (SEA's) are identified based on their values for representativeness, threat status and rarity, diversity, stepping stones, and overall uniqueness in accordance with Schedule 3 of the Unitary Plan. These factors are summarized below:

- Representativeness – example of an indigenous ecosystem that contributes to the 10% of the natural extent of each of Auckland's original ecosystem types in each ecological district.
- Threat Status and Rarity – Habitat that has been assessed using the IUCN threat classification as threatened, habitat of threatened fauna or flora, indigenous vegetation in LENZ IV <20%, indigenous vegetation within indigenous wetlands or dunes.
- Diversity – Extends across at least one environmental gradient, supports a typical species richness or species assemblage for its type.
- Stepping Stones Migration pathways, buffers – facilitates movement of fauna across the landscape, buffer for protection areas, part of a network of sites that cumulatively provide habitat.
- Uniqueness/Distinctiveness – fauna or flora endemic to the Auckland region, unusual combinations of species, type localities, intact sequence of outstanding condition, largest specimen or population.

All SEAs within the Ngakoroa catchment and the criteria that they meet are summarised below in Table 6. Only four SEAs occur within the structure plan area; two are Terrestrial SEAs consisting of remnant forest fragments (SEA_T_530 and SEA_T_530b), and two are Marine SEAs containing areas of coastal and riparian vegetation associated with the inner Drury-Opaheke Creek and the top of Ngakoroa Stream (Nathan, 2017).

The terrestrial SEA's at the Ngakoroa Stream mouth include records of nationally or regionally threatened plant species including native oxtongue (*Picris burbidgeae),* kaikomako *(Pennantia corymbose),* korokio (*Corokia cotoneaster*), mingimingi (*Coprosma propinqua var. propinqua),* and small-leaved kowhai (*Sophora microphylla)*.

None of the SEAs within the Ngakoroa catchment are classified as having unique or distinctive characteristics. Areas that qualify for this classification tend to be those that are known to contain rare endemic species or natural habitats that are in outstanding condition.

Table 6: Significant Ecological Areas in Ngakoroa Catchment (Schedule 3 SEA - Terrestrial Schedule)

Significant Ecological Area	Nearest Ecoline	Representativeness	Threat Status and Rarity	Diversity	Stepping Stone / Migration pathway / Buffer	Uniqueness or distinctiveness
SEA_T_530	Stream Mouth		✓		✓	
SEA_T_530b	Stream Mouth		✓			
SEA_T_79	1333 Gt South Rd	✓	✓	✓		
SEA_T_80		✓	✓			
SEA_T_81	1361 Gt South Rd	✓	✓			
SEA_T_4365		✓	✓			
SEA_T_4500	44 Old Coach Road		✓			
SEA_T_4364	Coulston Road	✓	✓			
SEA_T_4363	Coulston Road	✓	✓			

Significant Ecological Area	Nearest Ecoline	Representativeness	Threat Status and Rarity	Diversity	Stepping Stone / Migration pathway / Buffer	Uniqueness or distinctiveness
SEA_T_5332	Reserve	✓	✓		✓	
SEA_T_5333		✓	✓		✓	
SEA_T_4505	Also Natural Stream Management Area 1644 Gt Sth Rd	✓	✓	✓		
SEA_T_4514			✓			
SEA_T_85			✓		✓	
SEA_T_86		✓	✓			
SEA_T_4369		✓	✓			
SEA_T_4370		✓	✓			
SEA_T_4368		✓	✓			
SEA_T_4366		✓	✓			
SEA_T_4367		✓	✓			
SEA_T_4369		✓	✓			
SEA_T_4371		✓	✓			
SEA_T_4372		✓				
SEA_T_5344		✓	✓	✓		
SEA_T_4373		✓				
SEA_T_5295		✓			✓	
SEA_T_4506		✓				
SEA_T_4464		✓				
SEA_T_4389		✓				
SEA_T_4387		✓				
SEA_T_4388		✓			✓	

The two Marine SEAs are described below:

SEA_M1_29b – Ngakoroa Stream Mouth

The 'SEA-M1' designation for this area means that it has been assessed to be particularly vulnerable to the negative environmental impacts of inappropriate subdivision, use and development.

Within the upper tidal reaches of Drury Creek there are a variety of marshes, grading from mangroves through to extensive areas of jointed rush-dominated saltmarsh, to freshwater vegetation in response to salinity changes. This same area is a migration pathway between marine and freshwater habitats for a number of different native freshwater fish species.

SEA_M2_29a

This area has been designated as 'SEA-M2', which indicates that it has been assessed as being more robust in terms of its resilience to negative environmental effects than those that are categorised as 'SEA-M1'.

This area is comprised of a variety of intertidal habitats ranging from sandy mud intertidal flats, to current-exposed rocky reefs and a variety of saline vegetation. Healthy and often expanding areas of mangroves grow in the shelter of the Whangamaire Stream, and Drury and Whangapouri Creeks and in the southern half of the Whangapouri Creek are notable eelgrass (*Zostera*) beds. Drury Creek is comprised of a variety of intertidal habitats ranging from sandy mud intertidal flats to current-exposed rocky reefs and a variety of saline vegetation. The area is includes a number of wading bird roosting sites, including important areas for the pied stilt. (Schedule 4).

Apart from SEAs there are also areas within the catchment that are protected through both Auckland Council covenants and, to a lesser extent, QEII National Trust covenants. Auckland Council covenants, which are often created through the subdivision consent process, are present throughout the catchment, although they tend to be more common in the southern half, with only three present within the FUZ (see Map 5, Appendix 1).

There are only two QEII covenants within the catchment, one that includes tributaries NGA_MAIN_46 & NGA_MAIN_47, while the other contains an area of vegetation adjacent to TRIB23_5.

2.9 Cultural and Heritage Values

This report does not attempt to provide an extensive background of the history and cultural association or values within the rohe of each tribe in the area. The brief summary presented here should not be considered in lieu of appropriate consultation for any subsequent enhancement opportunities or projects.

In April 2017 a Deed of Settlement was signed between the Crown and Ngāti Tamaoho, a Waikati-Tainui hapu whose area of interest encompasses the Ngakoroa catchment. This Deed of Settlement included a statutory acknowledgement of Ngāti Tamaoho's traditional association and continuing interest in a number of areas covered by this Watercourse Assessment, including Ngakoroa Creek and its tributaries, as well as Raventhorpe Scenic Reserve. This statutory acknowledgement enhances the ability of the iwi to participate in RMA processes in relation to these areas.

A cultural impact assessment was prepared by the Ngāti Tamaoho Trust (2015) for the Bremner Road Special Housing Area in Drury, which is located partially within the Structure Plan area. Cultural considerations highlighted in this report, with regard to the freshwater environment, included:

- Improving the health of the streams and estuary within the area;
- Incorporation of water sensitive design into the construction of new infrastructure, including the use of pervious paving, reuse of roof runoff, incorporation of stormwater treatment, and alternative wastewater disposal;
- Removal of existing culverts and replacement with bridges;
- Poisoning and removal of crack willow trees;
- The incorporation of esplanade reserves along existing streams.

There is limited information available on other potential archaeological sites within the Ngakoroa catchment however histories and cultural narratives suggest that these areas were used for settlement and procurement of resources (Brown and Brown 2017).

2.10 Community Involvement

The environmental charity Sustainable Coastlines has collaborated with Auranga, the large subdivision project in Bremner Rd, Drury, to undertake litter removal and native planting along the Ngakoroa Stream since 2017.

Auranga's partnership with Sustainable Coastlines is part of its commitment to mitigate adverse effects on the natural environment, which includes incorporating rain gardens and landscaped wetlands into the development of the subdivision. Whilst there were no other notable community groups in the area, new development and residents in the area provide an opportunity for potential community stream projects in the future.

3.0 Watercourse Management

3.1 Management Zones

Eight management zones have been identified based on reaches with similar characteristics, values, and pressures (see Map 7, Appendix 1 for the locations of these areas). General issues and pressures that are common across the management zones within the FUZ are outlined in Section 3.1.1, while the overarching themes identified in management zones outside of the FUZ are addressed in Section 3.1.2.

Further issues and pressures specific to each management zone are outlined in Sections 3.1.3 to 3.1.10. Specific enhancement opportunities within each management zone are presented in Section 6.0.

Refer to Map 1 in Appendix 1 for an overview of stream names and tributary codes referred to throughout the report.

Many of the common pressures on watercourses within the Ngakoroa catchment result from historical and existing rural land uses (see Table 7). The majority of the catchment remains zoned for rural countryside living, mixed rural land use, and production zones. The production zones include the largest horticultural production area in Auckland, focused on the elite and prime soils in this region.

Proposed future growth and development within the Future Urban Zone also poses potential issues and pressures on watercourses within the catchment. There is, however, an opportunity to remedy and mitigate existing and future pressures through the Greenfields development process. Overarching recommendations associated with urban development are outlined below, with further specific management actions identified within Management Zones 1 and 2 which are within the Future Urban Zone.

In terms of this report, the proposed management approach is aimed at informing the development process whilst supporting the delivery of stream and water sensitive design outcomes and enhancing ecological and amenity functions by: providing core baseline data for preparation of ecological reports, Stormwater Management Plans and integrated development planning processes.

For the southern, rural catchment, an overarching management approach is outlined below with reference to the Runciman Precinct Plan, and mechanisms to achieve ecological enhancements through rural subdivision processes in the Unitary Plan.

3.1.1 Overarching recommendations for future urban development

Terrestrial Ecological Outcomes

- Use of native tree species planting, including street trees, to extend and connect existing riparian networks.
- Protection and enhancement of areas of significant habitat, as well as incorporating buffers to protect sensitive habitats, improve weed control, and facilitate natural regeneration processes.
- Support the development of conservation corridors to promote ecological connectivity.
- Support local community group objectives and efforts to preserve and enhance native ecosystems.
- Retain and enhance existing native vegetated areas in the catchment, whether classified as SEAs or not.
- Implementation of weed and pest control programs for restored reaches within the FUZ, with infill planting of native species where large areas of weeds are removed.

Freshwater Ecological Outcomes

- Strongly advocate for the preservation of all remaining open watercourses within the catchment, both permanent and intermittent.
- Streams and wetlands in the catchment are only to be piped and culverted in exceptional circumstances where no other practical alternative exists. Any diversion of watercourses should consider the groundwater recharge implications and maintain pre-diversion hydrology and habitat. Existing groundwater seepages should also be considered.

- For essential stream crossings, bank-to-bank bridges with minimal riparian and stream bed disturbance are preferred.
- Any new culverts or stream structures should employ best-practice design to allow for the unimpeded passage of native fish.
- Removal of online ponds to address the associated impacts on water quality and freshwater ecology.
- Where appropriate, restore hydrology and channel morphology to reflect a state prior to the impacts of culvert damming and/or stock access (notwithstanding impacts of existing and future land use).
- Where the topography and location of ponds or pugged riverine wetlands is suitable, options should be considered for the creation of stormwater treatment wetlands.
- Enhancement of streams and wetlands, especially those with no riparian vegetation, to a minimum of 10 m riparian width on both banks.
- Removal of exotic riparian species, and replace with native species to a minimum of 10 m width on both banks.
- Monitor stream bank erosion after development and remedy or mitigate identified erosion impacts.
- Remediation of barriers to fish passage, through the removal or retrofitting of problem culverts.

Stormwater Outcomes

- Advocate for best practice stormwater management controls in accordance with the principles identified for Flow 1 areas (AUP E10) in consideration of observed erosion susceptibility.
- Provide stormwater management to mimic as far as practical the pre-development hydrology.
- Incorporate best-practice water-sensitive design devices, including rain gardens, swales, rain tanks and permeable pavements, to reduce impacts of increased stormwater due to development.
- At-source (or as close as possible) stormwater management methods are preferred. Where specific site constraints require centralised devices, their proposed efficiency should be considered.
- Stormwater design should, where required and following reasonable mitigation measures, consider erosion protection. This is because the watercourses in this catchment are particularly susceptible to erosion.
- Promote diffuse flows to the Coastal Marine Area (CMA).
- Treatment of areas that generate high levels of contaminants.
- Promote reduced soil compaction during development and promote infiltration options.
- Encourage sensitive design that incorporates sediment control, as well as minimising impermeable areas, particularly during development.
- Empower communities through promoting and sharing water-sensitive design and environmental information and actions.

3.1.2 Overarching recommendations for rural land uses

Terrestrial Ecological Outcomes

- Protection and enhancement of areas of significant habitat, including incorporating buffers to protect sensitive habitats, improving weed control, and facilitating natural regeneration processes.
- Extension of SEA areas to seek to reduce fragmentation and edge area across the landscape and connect to other existing remnant forest patches or SEAs.
- Monitoring of covenanted areas to ensure appropriate stock exclusion, weed and pest control is undertaken.

Freshwater Ecological Outcomes

- Contact landowners to provide education regarding protection and management of waterways, and wetlands, landowner responsibilities, and supporting programmes and funding such as the Environment Initiatives Fund, or Trees for Survival.
- Seek implementation of potential enhancement opportunities through subdivision including where appropriate and in accordance with the Runciman Precinct Plan:
    - Removal of barriers to fish passage through removal/retrofitting of problem culverts

- Restore the hydrology of historic wetlands
- Removal of online ponds to address the associated impacts on water quality and freshwater ecology.
- Remediate existing erosion issues

- Enhancement of streams and wetlands, especially those with no riparian vegetation, to an average of 20 m width on both banks, with a minimum of 10 m on each bank.

Poor riparian vegetation and accessible to stock

Wide pastoral streams dominated by macrophytes

Farm drainage

Riverine wetlands formed in gullies impacted by stock

Market gardens

Willow-dominated main stream

Large bedrock cascade on NGA_MAIN_25

Hard-bottomed headwater stream under native forest canopy (TRIB17_29)

Soft-bottomed headwater streams in native forest (Raventhorpe Scenic Reserve)

Hard-bottomed main stream in native forested gully (NGA_MAIN_29)

Large (4 ha) online dam at NGAWEST_6

Figure 3: Overview of representative landscape and stream characteristics within the Ngakoroa catchment

Table 7: Common pressures across management zones in the Ngakoroa Catchment

Pressure	Description	Management Zones							
		1	2	3	4	5	6	7	8
Sedimentation within catchment	Increased sediment deposition resulting in habitat changes, loss of interstitial space, reduced availability of food supply and reduced spawning habitat for fish species	✓	✓	✓	✓	✓	✓	✓	✓
	Increased suspended sediment impacts macroinvertebrate feeding and damages fish gills	✓	✓		✓	✓	✓		
	Increased suspended sediment increases temperatures and thus lowers dissolved oxygen		✓		✓		✓		
Loss of riparian margin vegetation	Reduced shading and thermal regulation	✓	✓	✓	✓	✓	✓		
	Reduced dissolved oxygen levels as a result of an increase macrophyte abundance and water temperature		✓	✓	✓	✓	✓		
	Reduced bank stability		✓	✓	✓		✓		
	Reduced filtering capacity								
	Reduced habitat and spawning habitat								
	Reduced riparian corridor connectedness and ecological connectivity								
	Reduced amenity and aesthetic values								
Stock access to waterways	Reduced water quality through faecal contamination	✓	✓			✓	✓		
	Reduced bank stability	✓	✓				✓		
	Increased suspended sediments and deposition		✓						
	Change in morphology and hydrodynamics of the watercourse								
	Loss of native riparian vegetation								
Drainage and piping of freshwater systems	Limited or prevented interaction with groundwater								
	Loss of habitat								
	Reduction in organic material retention as a food source		✓						
	Reduction in particle retention for the assimilation of nutrients, protecting downstream receiving environments		✓						
	Change in flow regime								
	Potential barriers to fish passage								

Pressure	Description	Management Zones							
		1	2	3	4	5	6	7	8
Online farm / amenity ponds	Reduced base flows in streams during summer months								
	Increase stream temperatures								
	Reduced dissolved oxygen levels		✓		✓		✓		
	Preferential habitat for exotic fauna and flora		✓		✓		✓		
	Change in flow regime				✓		✓		
	Potential barriers to fish passage								
Agricultural source contaminants	High suspended or deposited sediment levels	✓	✓		✓	✓	✓		
	Low dissolved oxygen	✓	✓		✓	✓	✓		
	High temperatures				✓				
	High nutrient levels								
	High heavy metal concentrations								
Fish passage barriers	Impacts on fish recruitment, abundance and population dynamics		✓	✓	✓	✓	✓	✓	✓
			✓		✓	✓	✓		✓
							✓		
Actual and potential future urban development pressures	Change in land use and the associated contaminants of concern;	✓	✓	✓	✓	✓	✓		✓
	Increased erosion, stream silt load and siltation of the Manukau harbour, particularly during development;	✓	✓	✓		✓	✓		
	Increased imperviousness and associated changes in hydrograph and impacts on watercourses, including increased potential for channel erosion and reduced base flows;	✓	✓						
	Loss of riparian vegetation;								
	Loss of first and second order streams, and wetlands through piping, diversions and altered topography;								
	Further potential barriers to fish passage with the development of more roads, private accessways, and associated culvert structures;								
	Increased fragmentation of natural vegetation areas reducing ecological connectivity;								

3.1.3 Management Zone 1 - Future Urban Zone: Main Ngakoroa Stream

Tributaries: NGA_MAIN_1 - NGA_MAIN_11

This management zone encompasses the main stem of the Ngakoroa Stream, which is oriented in a north-south alignment and discharges to Drury Creek just to the west of the intersection between SH 22 and SH 1. This area is designated as a Future Urban Zone within the Drury West Structure Plan, so extensive residential subdivision is planned here in the future.

Characteristics:

The terrain in this area is gently undulating and the current land use generally consists of lifestyle blocks, with the stream running through paddocks used for cattle and horse grazing.

The lower reaches of the Ngakoroa Stream within this Management Zone are up to 10 m wide and 1.5 m deep and are dominated by silt/sand substrates. Riparian vegetation throughout this area is largely contiguous and mainly consists of exotic trees, such as large willows, which provide the majority of channel shading and in-stream habitat structure via their extensive root systems.

Table 8: MZ1 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Limited existing public open space or riparian reserves.	Consider potential to implement esplanade reserves along both banks of the main Ngakoroa Stream as part of the provisions for subdivision consenting.
Willow-dominated riparian vegetation	Progressively replace willows with native plantings where possible in order to maintain bank stability and stream shading while improving riparian vegetation condition.
Concrete bridge over Ngakoroa Stream with pilings on TRB exposed due to scour on inner meander at 792-754 Runciman Rd (NGA_TRIB9_1). See Figure 33.	Undertake an urgent assessment of the bridge structure and arrange for the design and installation of scour protection around the exposed piers. This issue was escalated to Council on 05/02/2018.

3.1.4 Management Zone 2 - Future Urban Zone: Ngakoroa Stream Tributaries

Tributaries: NGA_TRIB1 - NGA_TRIB9a; PAH_MAIN_1 – PAH_MAIN_9; PAH_TRIB1 – PAH_TRIB2

This management zone includes all of the tributaries off the main stem of the Ngakoroa Stream within the Future Urban Zone, as well as the Pahurehure Inlet Tributary to the north-west of the Ngakoroa Stream. The tributaries to the west of the main stem generally flow towards the north-east, with those on the eastern side flowing north-west.

As with Management Zone 1 above, this area is designated as a Future Urban Zone under the Drury West Structure Plan, and is therefore zoned for future residential subdivision.

Characteristics:

This area features terrain that is relatively flat, with land use dominated by agriculture, which mainly consists of cattle grazing. Streams within this zone exhibit high levels of sediment, high macrophyte coverage and notable levels of stock damage, particularly along NGA_TRIB3 and NGA_TRIB8b.

Riparian vegetation tends to be sparse and dominated by exotic species, while artificial straightening of streams is evident along a number of tributaries, including NGA_TRIB3, NGA_TRIB8 and NGA_TRIB9.

Table 9: MZ2 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Watercourses and historic wetlands have been modified to become straight deep channels and extensively fragment the ecological landscape.	Re-meandering of modified watercourses, consider daylighting options, and formation of contiguous green corridors. See EO1, EO2, EO6, EO7, EO8, EO9 (Section 6.0)
High water table and flood prone areas	Expected limitations on development within floodplains provide opportunities for the creation of public open space for passive recreational use combined with stormwater management. This could include detention basins, integrated with naturalised stream corridors to increase sinuosity with consideration of conveyance capacity (see EO7; Section 6.0)
Four culverts under the rail corridor intersecting first order tributaries of NGA_TRIB3 were overgrown with blackberry and gorse and inaccessible to determine condition, particularly from the outlet (647 Burtt Rd). Asset IDs: NGAPR_015, NGAPR_016, NGAPR_017	Refer maintenance recommendations to the appropriate authority (e.g. Kiwirail)
Poor condition of numerous private culverts on farm tracks	Advocate for the removal of redundant farm culverts through development
Stock damage to banks and watercourses	Advocate for the fencing and planting of riparian margins through the development process
Limited existing public open space or riparian reserves	Consider potential to implement esplanade reserves on Pahurehure Inlet tributary, and Tributaries 3 and 8 through future development.
Online ponds	Remove/remediate ponds to address associated impacts on water quality and freshwater ecology (see EO4, EO5; Section 6.0)
Barriers to fish migration within the Ngakoroa catchment	Remediate barriers to fish passage, namely: The perched culvert and its outlet structure (Asset IDs NGAPR_065 and NGA_139 respectively) which are located on NGA_TRIB3_4; A culvert located on PAH_MAIN_5 (Asset ID: NGAP_048), which is perched by 0.3 m; A perched PVC pipe (Asset ID: NGAP_050) located on PAH_TRIB2_2.
Culvert under shared driveway on NGA_TRIB8_6 presents a flood risk to non-habitable floors and access to properties (see Asset ID NGA_056)	Investigate remediation of undersized culvert to prevent flooding issues (see EO7; Section 6.0)

3.1.5 Management Zone 3 – Rural Zones: Bombay Residential Subdivision

Tributaries: TRIB24

The Bombay Residential Subdivision Management Zone incorporates an area around the township of Bombay that has been zoned as Residential – Rural and Coastal Settlement Zone under the Unitary Plan. It incorporates the uppermost sections of two tributaries within the larger TRIB24 area, which flow to the west under SH 1 just north of the Bombay interchange centred around the Bombay Rd, Paparata Rd intersection

Characteristics:

This zone is currently undergoing subdivision, with formerly agricultural land being converted into residential properties, and is notable for being the only area in the Ngakoroa catchment outside of the FUZ that is serviced by Council-owned stormwater infrastructure

Issues that were recorded in this zone include potential flooding risks to properties (anecdotal evidence from residents at Bombay Rd, Christa Place, and Paparata Rd), significant erosion within stream channels, and damaged public stormwater assets on Bombay Rd that require repair or replacement. Other maintenance actions are also recommended for public infrastructure immediately downstream, under Great South Rd.

Table 10: MZ3 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Resident at 117 Bombay Rd has constructed a stormwater diversion to direct surface runoff around her property (in response to flooding experienced), which has involved alteration of stormwater flows towards the southern perimeter of her property (see miscellaneous point on TRIB24_17). The reticulated stormwater network passes to the north towards a detention pond at the intersection with Lawrence Carter Drive.	Confirm that residential development is undertaken in accordance with consent conditions and management plans, particularly in relation to stormwater management and the location of overland flow paths.
Erosion protection maintenance issues at Bombay Rd and Christa Place (SAP ID 3000039153 and 2000322225)	Maintenance of rock rip rap placement to mitigate erosion issues. Implement erosion protection measures downstream of the rock rip-rap area on TRIB24_18, such as riparian planting and reinforcement of the stream channel using additional rip-rap or geotextile.
Damaged stormwater infrastructure assets identified as requiring remediation due to erosion issues and public safety concerns (see Section 4.7)	Undertake full engineering assessments of these assets with a view to rectifying the identified issues through repair or replacement.

3.1.6 Management Zone 4 – Rural Zones: Market Gardens

Tributaries: TRIB11_11 – TRIB11_12

The Market Garden Management Zone is made up of two main areas of market gardening activity. The smaller of these is located immediately south of Ararimu Rd between Great South Rd and SH1, while the main market gardening area within the catchment begins just south of Ingram Rd to the west of SH1 and Portsmouth Rd to the east and extends all the way to the southern end of the catchment on both sides of the motorway.

This area includes land zoned both for Mixed Use and Production.

Characteristics:

Market gardening is a key land use within the Ngakoroa catchment, which contains some of the country's most productive soils. Soil is recognised as a critical resource, particularly in elite and prime arable land such as is present within this area. The loss of topsoil through erosion is a loss to the grower and also has significant adverse effects associated with sedimentation of streams, and ultimately the coastal environment. In the case of the Ngakoroa catchment, the ultimate receiving environment for soil that is washed off market garden areas is the Pahurehure Inlet, which leads to increasing sedimentation of the Manukau Harbour.

Erosion of productive soils and sedimentation of waterways is a major issue for the Ngakoroa catchment, as well as on a national scale. The 'Our Land' report by the Ministry for the Environment & Stats NZ (2018), found that the national mean rate of soil erosion is 720 tonnes per km^2 per year and, in 2015, economic losses due to soil erosion and landslides were estimated at $250 Million to $300 Million per year.

Common issues that were recorded throughout this management zone included a high degree of sediment runoff from market gardening activities, which resulted in excessive fine sediment loading within the adjacent stream tributaries (see Appendix 1).

Streams also tended to contain excessive macrophyte and periphyton growth as a result of both the amount of sediment present and low levels of channel shading due to a lack of significant riparian vegetation. It is also likely that nutrient runoff from fertiliser applied to market gardens is largely responsible for the amounts of macrophytes and periphyton recorded in these areas.

Throughout this management zone in-stream conditions tended to be largely homogenous, with uniform flow conditions and little habitat present for aquatic fauna.

Large online ponds, presumably used for irrigation, were present on TRIB11 and TRIB28 and were dominated by exotic vegetation.

Table 11: MZ4 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Localised areas of significant sediment deposition caused by soil runoff from adjacent market gardens	Ensure that horticultural landowners are keeping sediment management systems up-to-date and well maintained so that sediment inputs to the surrounding watercourse are minimised, following Auckland Unitary Plan requirements and industry best practice guidelines, such as Barber (2014). Consider undertaking targeted investigations within the Ngakoroa catchment to ascertain the level of compliance with permitted activity requirements for market gardening under the Unitary Plan. Encourage landowners to enhance and protect riparian zones to allow an effective buffer between market gardening activity and adjacent streams. Incorporate the use of vegetation to filter surface runoff to retain as much sediment on land as possible.
Areas of high periphyton and macrophyte abundance	Encourage horticultural landowners to reduce fertiliser inputs in concert with improved sediment management systems to reduce direct runoff into streams. Investigate options for the creation of wetland treatment systems to capture and absorb excess nutrient runoff from agricultural areas to improve water quality in downstream areas of the catchment.

3.1.7 Management Zone 5 – Rural Zones: Ngakoroa Main Stream

Tributaries: NGA_MAIN_12 - NGA_MAIN_23; NGA_MAIN_34 - NGA_MAIN_46

This management zone encompasses all of the reaches along the main stem of the Ngakoroa Stream south of the FUZ, with the exception of those between NGA_MAIN_24 and NGA_MAIN_33, which are included within Management Zone 8 due to changes in channel morphology and riparian vegetation within that section (see Section 3.1.10).

This area includes land zoned for Countryside Living, to the north, and Mixed Use further south.

Characteristics:

Stream reaches within this management zone are predominantly wide and soft-bottomed, with exotic vegetation present along the riparian margins. The exotic aquatic macrophyte *Egeria densa* is also commonly found throughout the length of the main stem of the Ngakoroa Stream.

Channel shading is good in the northern reaches of this management zone, with much of the in-stream habitat structure and shading provided by large willow trees along the banks.

Land-use within this area is almost entirely agricultural, mainly comprising cattle grazing. Stock have access to one or both stream banks for the entire section of stream from NGA_MAIN_11 to NGA_MAIN_19, with the level of recorded stock damage to these areas also reflecting this.

There are no artificial barriers to fish passage along the length of the main stem of the Ngakoroa Stream until the Auckland Council flow monitoring weir, which is located immediately upstream of a waterfall on NGA_MAIN_58. A large number of natural cascades and waterfalls form the main barriers to fish passage downstream of this point, therefore there are no suggested actions for fish passage remediation in this Management Zone.

Table 12: MZ5 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Limited existing public open space or riparian reserves.	Consider potential to implement esplanade reserves along both banks of the main Ngakoroa Stream as part of the provisions for future subdivision consents where applicable, particularly within the Runciman Precinct where these may extend existing reserves or provide continuous linkages from the FUZ (e.g. EO10, EO13).
Willow-dominated riparian vegetation	Where riparian planting or environmental enhancement may be required as a condition of consent, consider options to progressively replace willows with native plantings where possible in order to maintain bank stability and stream shading while improving riparian vegetation condition.
Stock damage to stream channel and banks	Encourage landowners to fence streams in order to prevent stock damage, with consideration of stock exclusion requirements under the Unitary Plan.

3.1.8 Management Zone 6 – Rural Zones: Ngakoroa Stream Tributaries

Tributaries: NGAWEST; TRIB11; TRIB14 - TRIB21; TRIB31 – 36; NGA_MAIN_70 – NGA_MAIN_74

This management zone includes all tributaries flowing to the main stem of the Ngakoroa Stream that are located to the south of the FUZ and outside of the Market Garden management zone (MZ4) outlined in Section

3.1.6. This includes the large Ngakoroa West sub-catchment (NGAWEST), which is notable for the two large online dams and numerous smaller online ponds that are located along it.

The majority of these tributaries are found in the Runciman Precinct area, which is zoned for Countryside Living, although a smaller number are found outside of the Runciman Precinct in the area zoned as Mixed Use.

The Runciman Precinct has been designated in the Unitary Plan as an area that is suitable for future subdivision, so streams within this zone are likely to be subject to increasing pressures associated with land development, although, conversely, there will also be increased opportunities to enhance the ecological value of these tributaries through conditions attached to subdivision consents.

Enhancement Opportunities that have been identified within the Runciman Precinct include EOs 10, 11, 14, 16, and 17 (see Section 6.0), which encompass actions such as ecological enhancement, improving forest connectivity and remediating barriers to fish passage. Two of these EOs, 11 and 14, extend across the border of the Runciman Precinct to the Mixed-Use zone.

The Mixed-Use land located outside of the Precinct is not zoned for intensive subdivision and is therefore less likely to afford the same opportunities to enhance stream values unless entered into voluntarily by the landowner.

Characteristics:

Streams within this management zone make up the majority of waterways within the Ngakoroa catchment. The surrounding land use is predominantly agricultural, comprising some areas of lifestyle blocks with other properties being larger-scale grazing land.

Streams within this area are almost entirely soft-bottomed, and riparian margins tends to be sparse and comprised of exotic vegetation.

A number of online ponds are present within this management zone, many of which appear to be used for aesthetic or recreational purposes, such as duck shooting. There are two large online dams located on the Ngakoroa West tributary, the larger of which is over 4 ha in size and the smaller being 1.1 ha. In addition there are a large number of smaller online ponds scattered throughout this area, such as a series of nine online ponds located upstream of NGAWEST_53 and a number of large ponds upstream of TRIB17_50.

The presence of large online ponds and dams can create significant issues within the catchment, for example increased erosion at outfalls, a risk of flooding downstream areas in the event of dam failure, decreased water quality within ponds, inlets and outlets creating barriers to native fish passage, and the ponds themselves providing of ideal habitats for aquatic weeds and pest fish species to proliferate.

The effects on stormwater flows from large online dams can be likened to the equivalent area of impervious surface as, unless they are correctly designed as stormwater detention ponds, they provide no effective stormwater holding capacity for rainfall. This means that these dams can result in increased variation in stream flow and higher erosion potential for the downstream catchment area.

Table 13: MZ6 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Online dams at NGAWEST_6 and NGAWEST_62 have erosion hotpots on NGAWEST_5 and NGAWEST_7 associated with them, respectively. Series of online constructed ponds located upstream of NGAWEST_53.	Remediate identified erosion hotspots to prevent continuing erosion and discharge of sediment during high flows. Removal or remediation of online farm ponds should be undertaken when rural properties undergo subdivision in order to address effects on water quality and fish passage. Consider cross-checking the location of identified online ponds with streamworks consents that have been issued to determine whether they are compliant with former District Plan and/or Unitary Plan rules.
Damaged culvert (Asset ID: NGAF_114), which acts as the outlet to the large online dam at NGAWEST_6. Pipes are displaced, with potential for failure.	Prioritise culvert for assessment and remedial action, due to potential for failure and flooding risk to downstream areas.
Significant fish passage barriers at Assets NGAF_137 & NGAF_142	Remediation of these two perched culverts, which form the outlet for the large dam on NGAWEST_62, to allow fish migration into suitable upstream habitat.
Poor condition of numerous private culverts on farm tracks.	Removal and/or remediation of degraded farm culverts to enhance fish passage and reduce potential erosion should be undertaken as and when rural properties undergo further development e.g. subdivision for residential lots.
Stock damage to stream channel and banks	Encourage landowners to fence streams in order to prevent stock damage, with consideration of stock exclusion requirements under the Unitary Plan.
Limited existing public open space or riparian reserves.	Consider potential to implement esplanade reserves along both banks of the main Ngakoroa Stream as part of the provisions for future subdivision consents, where applicable.
Multiple dead eels found in along TRIB11_5 (see Section 4.1.2)	Undertake site inspection and provide pollution prevention education to commercial operations in the vicinity of this area to ensure that no wastewater or other substances are being discharged to stormwater.

3.1.9 Management Zone 7 – Rural Zones: Headwater Native Forest Fragments

Tributaries: NGAWEST_11, NGAWEST_12, NGAWEST_28, NGAWEST_31; NGAWEST_27; NGAWEST_24; TRIB16_8 – TRIB16_10; TRIB15_11; TRIB17_58, TRIB17_9; TRIB17_33 - TRIB17_34; TRIB17_27 - TRIB17_28; TRIB17_51, TRIB17_41; TRIB17_38

This zone encompasses ten isolated native forest fragments that are located around first-order streams at the headwaters of tributaries in the middle section of the Ngakoroa catchment. This management zone includes rural areas that have been zoned for Countryside Living within the Runciman Precinct, as well as areas outside of it that are zoned for Mixed Land-use.

Characteristics

Most of these forest fragments are small, less than 5 ha in size, with the exception being Raventhorpe Scenic Reserve which is 21 ha.

Vegetation in these areas tends to be dominated by large native canopy trees such as totara and puriri, with rewarewa and nikau also being common in the understorey. Groundcover largely consists of ferns, and deep leaf litter was present within the floodplains.

The majority of tributaries in the native forest fragments are shallow soft-bottomed streams, although some boulder and cobble is present in TRIB17_9 within Raventhorpe Scenic Reserve. A number of these tributaries are intermittent due to being located at the top of their respective catchments and with limited stream flow.

Low-gradient banks with extensive boggy floodplains are common to most of these areas, with the high levels of shading and deep leaf litter showing potential for these sites to be used for banded kokopu spawning.

Banded kokopu were captured in both TRIB15 and TRIB16, highlighting the value of the forest habitat within this Management Zone for native fish species.

The presence of wild deer was noted within Raventhorpe Scenic Reserve with hoof prints and trails through the undergrowth observed. While the relatively small size of the reserve is unlikely to support a large deer population, they are still likely to impact the vegetation structure and function within this area through browsing pressure. Given the limited size of the reserve and isolation from other forest areas, a targeted control programme should be able to eradicate deer relatively easily.

Increasing the ecological function of these headwater forest fragments will involve improving connectivity with other areas of native vegetation on a landscape scale, including nearby areas that are subject to Council or QEII covenants. This would most logically be achieved by increasing riparian planting throughout the catchment to utilise the existing natural corridors for wildlife movement that are created by the stream network. Fencing existing areas of native forest to protect from stock damage, as well as the control of pest plant species, should also be undertaken to help preserve the integrity of the native vegetation present.

Table 14: MZ7 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
Remnant forest fragments disconnected from the riparian corridor	Consider opportunities to protect existing forest fragments and to develop ecological corridors across the wider landscape. Use of native riparian planting to enhance connectivity and create ecological corridors throughout the Ngakoroa catchment (see EO11, EO14; Section 6.0). Note that EO14 is partially within the Runciman Precinct, while EO11 is completely outside it.
Lack of public access to Raventhorpe Scenic Reserve	Investigate options for instituting public access to the reserve from the surrounding road network.
Wild deer in Raventhorpe Scenic Reserve	Undertake control operations to eradicate deer in the reserve to reduce browsing pressure on native vegetation.
Use of forest fragments by pest animals	Encourage and support landowners to undertake possum, stoat and rat control within forest fragments to reduce impacts on native flora and fauna.

3.1.10 Management Zone 8 – Rural Zones: Hard-Bottomed Native Gully

Tributaries: NGA_MAIN_24 - NGA_MAIN_33

The Hard-Bottomed Native Gully management zone is located on the main stem of the Ngakoroa Stream and runs parallel to Great South Rd on the eastern side of the Ngakoroa catchment for approximately 3 km between NGA_MAIN_24 and NGA_MAIN_33. It is located at roughly the midway point of the catchment and straddles the areas zoned for Countryside Living and Mixed Land-use.

Characteristics

A notable feature of this management zone is the steep-sided, incised gully, predominantly surrounded by native bush, through which the Ngakoroa Stream flows. Throughout this area there is an increased level of habitat heterogeneity, as the streambed comprises a high percentage of bedrock and boulder substrate when compared to the silt/sand-dominated reaches that predominate throughout the rest of the catchment.

Land-use within this zone includes both large residential lots in established subdivisions, such as Martyn Farm Estate on Great South Rd, and agricultural areas, where the stream runs through paddocks using primarily for cattle grazing.

The riparian margins within this zone tend to be more contiguous than for the majority of the catchment, with widths of at least 10 m.

Within this Management Zone is one of only two Natural Stream Management Areas within the Ngakoroa catchment, which runs closely alongside Great South Rd and also incorporates the Martyn Farm Estate esplanade reserve area, which is vested with Council.

Throughout this zone there are five rocky cascades as well as five waterfalls. These natural features are significant barriers to fish passage and, although they are likely to be passable by climbing species, their presence can be expected to restrict the numbers of these fish that are able to migrate further upstream in the catchment.

Although native bush is the dominant vegetation type present, there are still large expanses of dense *Tradescantia* that comprise the majority of the groundcover along much of the riparian margins, and which is likely to be a limiting factor for the regeneration of native vegetation in these areas.

The middle section of this zone, which is bordered on both banks by agricultural land use, lacks the same width of riparian vegetation as the upstream and downstream sections and comprises more exotic vegetation, such as willows.

Illegal dumping appeared to be an issue within the Martyn Farm Estate esplanade reserve, with used car tyres and cardboard found along the true right bank adjacent to Great South Rd.

Table 15: MZ8 Issues and Objectives

Specific Issues	Suggested Objectives and Actions
High ecological value, as well as potential high amenity value	Consider potential to implement esplanade reserves along both banks of the main Ngakoroa Stream, particularly within the Runciman Precinct, as part of the provisions for future subdivision consents, where applicable. These esplanade reserves could incorporate infrastructure, such as tracks and stairs, to enable safe recreational access to the stream, particularly within the steeper area of the gully system. Consider potential implementation of water quality monitoring at identified potential swimming locations for 'swimmability', such as at EO10 or downstream of the waterfall on NGA_MAIN_29.
Pest plant species within the riparian corridor on private land (e.g. NGA_MAIN_23, NGA_MAIN_29, NGA_MAIN_32)	Encourage and support landowners to undertake weed control within the riparian margins on their property, especially the removal of large areas of tradescantia and reed sweet grass.
Tradescantia within Martyn Farm Estate esplanade reserve (NGA_MAIN_32)	Council to undertake weed control in reserve to enhance regeneration of native bush.
Illegal dumping in Martyn Farm Estate esplanade reserve (NGA_MAIN_32)	Remove existing rubbish (including used car tyres, cardboard). Undertake periodic monitoring of this area to ensure that it doesn't become an established illegal fly-tipping location.

4.0 Summary of Findings

Watercourse assessments for the Ngakoroa catchment were undertaken between January and April 2018, with physical variables being reflective of summer conditions. Average daily rainfall within the catchment over this period was 3 mm, with the heaviest daily rainfall of 44.5 mm occurring on 15 April 2018. A total of 42.5 mm of rain fell on 2 February, while both 28 January and 25 March experienced 18.5 mm of rain.

Due to access restrictions not all streams identified in the scoping map were able to be assessed in the field. Desktop analysis was undertaken on stream sections that could not be accessed (see Section 4.1.1 for further details).

Refer to Map 1 in Appendix 1 for an overview of stream names and tributary codes referred to throughout the report.

The Future Urban Zone within the Ngakoroa catchment is located at the northern, downstream end of the catchment and extends from Drury in the north to Runciman in the south. The remainder of the catchment, which comprises 81% of the total stream length within the catchment, extends to the south past Bombay and includes land zoned for Countryside Living, Mixed Use, and Production.

The main stream network in the Future Urban Zone consists of the main stem of the Ngakoroa Stream and its tributaries. The Ngakoroa Stream is oriented in a north-south alignment and discharges to Drury Creek just to the west of the intersection between SH 22 and SH 1. A secondary, much smaller, catchment designated as the unnamed Pahurehure Inlet Tributary is present to the west of the lower reaches of the Ngakoroa Stream and discharges directly into Drury Creek.

The general character and physical variables for these reaches are described in Section 4.1.1 below and summarised in Table 10. Refer to Maps 3 and 4 (Appendix 1) for an overview of bank and channel modification and erosion issues. General patterns in riparian condition are outlined in Section 4.1.3 and summarised in Table 13. Refer to Map 5 for an overview of overhead cover, significant ecological areas, and notable trees.

Additional information on freshwater ecological values including habitat types, fish communities and barriers to fish passage, the marine receiving environment, and wetlands are outlined in sections 4.2 to 0. Refer to Map 6 for an overview of locations of fish observations and recorded barriers to fish passage.

4.1 Ecoline

Throughout the Ngakoroa catchment the streams generally appear to follow natural flow paths. Although there is human modification of streams in most areas of the catchment, with 18% of the total stream length showing evidence of channel straightening, entirely artificial channels are absent.

In total, 89.8 km of stream length - made up of 497 individual reaches - was assessed as part of this investigation. The attributes of the stream reaches assessed using the Watercourse Assessment methodology are outlined below.

4.1.1 Physical Attributes

The vast majority of the catchment (98% by stream length) drains into the Ngakoroa Stream, with the remainder draining to the Pahurehure Inlet Tributary at the very northern end of the catchment, which consists of approximately 2 km of total stream length.

Due to access restrictions, some areas of the catchment were unable to be assessed in the field and therefore had to be assessed via desktop only. These areas amounted to 13,047 m in stream length over a total of 73 reaches, which represents 15% of both the total stream length and total number of reaches within the Ngakoroa catchment.

Extensive modification of channel morphology and hydrology was observed, with 30% of the total stream length assessed altered by some form of artificial widening, straightening, deepening, and in a few instances

reinforced with lining (see section 4.9). While no overall spatial patterns of modification were evident, almost the entirety of TRIB11 was modified, as were significant portions of TRIB3 and TRIB8 within the FUZ.

Stock damage impacting channel morphology was also noted on 24% of the total stream length. These modifications were common and spread throughout the catchment reflecting the predominantly agricultural land uses.

Floodplain connectivity was assessed to be either frequent or often on 31% of the total stream length surveyed. The remaining 69% had occasional or rare floodplain connectivity. The majority of streams within the FUZ had low levels of floodplain connectivity despite being located in the low-gradient downstream reaches of the catchment, which indicates the extent of potential stream modification and drainage, lowering the water table, that has occurred in this area. Areas with extensive floodplains occur along TRIB3, TRIB8 and TRIB8b (see Sections 4.1.1.2 and 4.1.1.3). Historic aerial imagery indicated that wetlands existed in these areas in the past, but were likely drained to create paddocks.

Sediment deposition was identified as a significant issue throughout the catchment, with active sediment deposition on average affecting 56% of stream bed area across all reaches surveyed. A total of 112 reaches spread throughout the catchment were assessed as having 100% active sediment deposition, as evidenced by loose unconsolidated sediments covering the stream bed. While the majority of these streams would have naturally been soft bottomed, in many instances the depth of loose unconsolidated sediment was >0.2 m and in some instances up to 0.7 m (measured by the depth the measuring staff would sink when dropped).

Bank erosion did not emerge as a major issue within this catchment, with only 5% of the stream length surveyed having erosion levels greater than 40%. Given the level of sedimentation observed, the source of the sediment is therefore is more likely attributable to land use, including runoff from pastoral landscapes, and also soil loss and erosion from exposed soil surfaces in horticultural areas. This is further evidenced by the localization of some of these sediment and erosion issues immediately adjacent to, and downstream of market garden areas. A photo map and schedule illustrating this is contained in Appendix 1.

Although erosion issues were generally uncommon throughout the catchment, 24 localised areas of bank erosion were present. A number of these areas of elevated bank erosion, and erosion hotspots were clustered within market gardens in the southern area of the catchment, and were likely a result of a lack of riparian vegetation combined with the intensive horticultural land use in the surrounding area.

Specific locations where high levels of bank erosion were recorded included NGA_MAIN_56, TRIB11_17, NGAWEST_19, NGAWEST_24, TRIB24_6 and TRIB24_19. Contributing factors to the erosion present in these locations appear to be mainly related to high flows carving out the soft, erodible soil that make up the banks, as well as the presence of poorly maintained in-stream engineering structures, such as culverts. Further information on erosion hotspots is provided in Section 4.10.

Assessment of the upper bank stability using a modified Pfankuch (1975) method indicates that only one very short reach within the FUZ (NGA_TRIB4a_1) was rated as excellent, with the remainder of streams within this zone being rated as fair or good. This trend existed throughout the rest of the catchment, with 96.5% of streams being rated as fair or good for overall stability. Only two reaches within the catchment, NGA_MAIN_21 and TRIB32_7, were rated as having poor upper bank stability. Fair to poor bank vegetation, providing low density root mass to stabilise banks, was the most common limiting factor of bank stability.

Stock damage was prevalent throughout much of the catchment, particularly along NGA_TRIB3, which exhibited severe stock damage along much of its length. The lower half of the Ngakoroa West tributary was also affected by stock, as was the majority of the main stem of the Ngakoroa Stream, outside of the FUZ from NGA_MAIN_11 to NGA_MAIN_19 and from NGA_MAIN_44 to NGA_MAIN_49.

The main Ngakoroa Stream, and its tributaries within the Future Urban Zone only are described further below.

4.1.1.1 Ngakoroa Stream

The lower 3 km of the main Ngakoroa Stream flows in a south-north direction through the future urban area from Runciman Rd to Ngakoroa Reserve at SH22 where the stream discharges to Drury Creek.

The stream is wide, run dominant, and largely maintains its natural morphology and extent of meander. The stream is dominated by mature willows which provide bank stability however in some areas, these have formed large debris jams and creating back-waters and pools. In these areas, the willow canopy extends across the full width of the channel.

Figure 4: Lower Ngakoroa Stream (NGA_MAIN_2-3)

4.1.1.2 Tributary 8 and Tributary 8b

Ngakoroa Stream Tributary 8 extends south from the main Ngakoroa Stream, intersecting properties dominated by residential and agricultural land use. The main channel has been historically straightened. This main channel flows from south to north and outside of the future urban area is referred to as NGAWEST (the main western sub-catchment of Ngakoroa).

Tributary 8b extends west from the main channel. This area has been extensively drained with a series of straightened farm drains, however an extensive floodplain covers this area.

Figure 5: Right - Tributary 8. Left – Overview of landscape of Tributary 8b showing network of drainage

4.1.1.3 Tributary 3

Ngakoroa Stream Tributary 3 is situated between the railway tracks and Burtt Road, west of the main Ngakoroa Stream. These reaches are characterised by incised channels, with high levels of exotic macrophyte cover and a dense gorse (*Ulex europaeus*) understory. The stream narrows in the upper reaches between NGA_TRIB3_4 and NGA_TRIB3_5. The mid-reaches were heavily modified by pugging which resulted in a poorly defined channel with an average wetted width of 1.8 m, with clear evidence of the full width of the constrained gully being regularly engaged to an average width of 4 m. This was dominated by aquatic macrophytes.

Figure 6: Representative reaches of Tributary 3

4.1.1.4 Pahurehure Inlet Tributary

The Pahurehure Inlet tributary is situated north-west of the main Ngakoroa Stream. The main stem extends from Karaka Road, flowing downstream into Drury Creek. The Pahurehure tributary intersects multiple property boundaries, which are predominately areas of pastoral land use.

The lower reaches have open stock access and were generally characterised by sparse canopy cover and exotic understory and groundcover, with some willow dominated reaches. A series of artificial farm ponds are located in the mid-reaches of the tributary. Sections of the tributary lack clearly-defined banks due to pugging. The upper reaches were generally characterised by incised channels.

Figure 7: Representative reaches of Pahurehure Inlet Tributary

Table 10: Summary of physical variables across the extent of watercourse surveyed

Total Length of Surveyed Watercourse (m)	89,946				
Total Length within FUZ (m)	17,040 (19 %)				
No. Reaches	497				
Class	**Permanent**	**Intermittent**	**Ephemeral/OLFP**		
% of total stream length	90%	8%	2%		
length of stream (m)	81,068	7,158	1,720		
	Mean	**Min**	**Max**		
Reach Length (m)	181	16	760		
Average Width (m)	1.75	0.00	10.00		
Depth (m)	0.29	0.00	9.00		
Bank Angle (degrees)	53	0	95		
Bank Height (m)	0.86	0.09	4		
Sediment Deposition (% accumulation)	56	0	100		
Adjacent Land Use	**Vegetation**	**Agricultural**	**Residential**	**Light Industry**	**Impervious Surface**
% of total stream length	16.6%	79.5%	3.4%	0.1%	0.4%
length of stream (m)	29,808	142,975	6,132	265	713
Dominant Substrate	**Artificial**	**Bedrock**	**Boulder**	**Cobble**	**Gravel**	**Silt/Sand**
% of total stream length	0.0%	4.1%	3.0%	1.0%	0.4%	91.5%
length of stream (m)	0	3,683	2,656	941	331	82,091
Channel Modification	**Widened**	**Straightened**	**Deepened**	**Lined**	
% of total stream length	7%	18%	4%	1%	
length of stream (m)	6,096	16,363	3,921	677	
Erosion Scarring	**≤20%**	**20-40%**	**40-60%**	**≥60%**	
% of total stream length	85%	10%	4%	1%	
length of stream (m)	153,457	18,500	6,337	1,193	
Stock Damage	**None**	**Minor**	**Moderate**	**Severe**	**NA**
% of total stream length	76%	15%	5%	4%	0%
length of stream (m)	68,016	13,387	4,104	3,423	0

Note: Adjacent Land Use and Erosion Scarring is assessed separately for the TRB and TLB, therefore total length is doubled

Table 11: Summary of Pfankuch bank stability assessment of the total length of watercourse (m)

	Excellent	**Good**	**Fair**	**Poor**
Land Slope (m)	12,737	53,540	13,163	10,304
Mass Wasting (m)	15,027	66,507	5,474	2,735
Debris Jam (m)	10,557	65,446	11,104	2,636
Bank Vegetation (m)	4,652	14,977	46,991	23,124
Overall Stability Index				
% of total stream length	3.1%	61.0%	35.5%	0.3%
length of stream (m)	2,811	54,764	31,890	279

Note: The Overall Stability Index is calculated for each reach based on the Land Slope, Mass Wasting, Debris Jam and Bank Vegetation metrics recorded for that reach.

4.1.2 Water Quality Attributes

A summary of contamination observed throughout the surveyed watercourses is provided in 18 and described below. Further details of pollution discharges, occurring at the time of the survey is provided in Section 4.11.1.

As outlined above, sediment discharges were a common factor impacting on water quality within the catchment, as evidenced by the extensive deposition of fine sediment within stream channels. Key locations with high sediment accumulation are outlined further in the memorandum in Appendix 1.

Anaerobic conditions represented the majority of contamination recorded, with 18% of the surveyed reaches affected. This type of contamination was common due to the prevalence of deep sediment deposits throughout the catchment, which tended to result in the formation of anaerobic conditions within the stream channel.

Only one incidence of hydrocarbon contamination was noted, which was in TRIB27_10. In this case a thin sheen of hydrocarbon was observed on the surface of the stream over part of the reach, along with a strong smell of fuel. The amount of hydrocarbon appeared to be relatively small and no source of the contamination was identified.

Two instances of contamination classified as 'Other' were recorded, the most serious of which was the discovery of at least eight dead eels in TRIB11_5, which appeared to have been killed by some type of discharge (Figure 8). This incident was reported to Auckland Council's Water Pollution Hotline (Ref. INR60207690) for further investigation.

The remaining contamination observation regarded an unidentified cloudy substance present within a pool on TRIB24_23.

Figure 8: Dead eels found in TRIB11_5

Table 12: Summary of watercourse contamination

Attribute	Number of observations
Sewage Fungus	0
Petroleum/Hydrocarbons	1
Anaerobic Conditions	87
Other	2

4.1.3 Biological Attributes

A summary of riparian vegetation characteristics is provided in . General patterns in riparian management are outlined below.

Riparian vegetation is important for maintaining stream health for the following reasons:

a. Maintaining stream bank stability;
b. Reducing contaminant and nutrient inputs to streams;
c. Maintaining suitable light and temperature conditions in streams;
d. Maintaining carbon inputs to streams;
e. Providing riparian and aquatic habitats.

Overall, riparian vegetation and vegetation cover across the catchment was poor. The catchment is predominantly agricultural, and consequently, pastoral grasses dominate the riparian corridor for nearly half of the streams surveyed. Narrow margins of mixed or exotic scrub (including gorse, hawthorn hedges, or other mixed to exotic scrub) and shelter belt canopies were also common. In the lower reaches of the Ngakoroa Stream both banks tend to be lined with large willow trees.

Intact native vegetation was rare, with native understory being found along only 12% of streams, a slightly higher proportion had native canopy species indicating the presence of remnant bush with damaged understory. The main areas where native canopy trees dominated tend to be around small headwater tributaries and along the main stem from NGA_MAIN_28 to NGA_MAIN_29 as well as NGA_MAIN_31 to NGA_MAIN_33. These forest types are noted in Singers *et al.* 2017 to be predominantly endangered taraire (WF9) and critically endangered puriri (WF7) forests which occupy the highly fertile soils in the south of the catchment that have been largely cleared for horticultural purposes (Figure 9.

The remaining fragments were typically small in size, and irregularly-shaped, with a high proportion of edge area in relation to internal area. This means that they are subject to 'edge effects', which commonly include increased colonisation by weed species and a reduction in the microclimatic conditions that would usually be present within forest areas. Pest species, such as possums and rats, are likely to utilise the forest habitat within these areas, which will impact the regeneration of native vegetation and presence of native bird, lizard and invertebrate species through browsing and predation pressure.

Figure 9: Large mature puriri at NGA_TRIB17_29

Small areas of critically endangered kahikatea forest (ecosystem type WF8, MF4) occur on NGA_TRIB15_1 NGA_TRIB11_3, and NGA_TRIB17_44,49,59). Not all of these areas are identified in current ecosystem extent mapping (Singers *et al.* 2017) or are listed as SEA's or covenanted areas. These areas have been greatly reduced in extent due to drainage and agricultural development and it is important to manage the hydrology and water table to preserve these areas (Singers *et al* 2017). Where possible, wetland restoration within the catchment should consider opportunities to recreate these forest types.

Figure 10: Kahikatea on NGA_TRIB15_11 Kern Rd (left) and remnant fragment on NGA_TRIB17_44 (right)

A buffer width of >10 m on either side of the stream has been recommended as a minimum requirement for indigenous succession reducing maintenance and weed infestation (Parkyn *et al.* 2000). However, the target width is 15 m or more for a higher likelihood that the buffer strip will support self-sustaining, low maintenance native vegetation (Parkyn *et al.* 2000). Less than 20% of the catchment had buffer widths exceeding 15 m. This represents a significant opportunity to increase indigenous biodiversity values within the catchment. For example, if the 30% of stream length that currently has no riparian buffer was to be planted to a minimum of 10 m, this would translate to 57 ha of additional planting, more than twice the area of the largest remnant forest fragment (Raventhorpe Reserve) within the catchment.

Overhead shading of 70% is predicted to be sufficient to restore small pastoral stream temperatures to <20 ^{o}C (Young *et al.* 2013). The upper water temperature limit set by the Auckland Council Water Quality monitoring objectives is 18 ^{o}C (Lockie & Neale, 2013).

Overhead cover is generally low throughout the catchment, with 61% of all streams having less than 50% cover and only 19% of streams having overhead cover of above 70%. The areas with high levels of overhead cover are generally found in the upper sections of tributaries where pockets of intact vegetation can be found, while the longest continuous stretch of high overhead cover, which extended for 1.9 km, was found on the main stem of the Ngakoroa Stream within Management Zone 8 (Section 3.1.10).

Streams featuring less than 10% overhead cover are common throughout the market gardening areas of the catchment (Management Zone 4; Section 0).

Restoration of riparian corridors was also observed with recent plantings <5 years old along approximately 10 km of stream, including the two headwater tributaries upstream of NGAWEST_17, isolated reaches along TRIB17 and a stretch of stream on TRIB11_1.

Figure 11: Recent extensive riparian revegetation on NGA_MAIN63

Figure 12: Riparian planting connecting remnant forest fragments at NGAWEST_23.

Table 13: Summary of riparian vegetation across the extent of watercourse surveyed						
Length of Surveyed Watercourse (m)			89946			
No. reaches (Ecolines)			497			
	Mean		**Min**		**Max**	
Percentage of intact vegetation within reach.	40		0		100	
Average Overhead Cover	**≤10 %**	**≤30%**	**≤50%**	**≤70%**	**≤90%**	**>90%**
% of total stream length	29%	18%	14%	18%	15%	4%
length of stream (m)	26,468	16,494	13,041	16,514	13,471	3,959
Average Riparian Width	**0m**	**≤5m**	**≤10m**	**≤15m**	**≤20m**	**>20m**
% of total stream length	33%	32%	19%	4%	5%	7%
length of stream (m)	57,312	56,770	32,625	6,909	9,402	12,857
Vegetation Tier Categories	**None**		**Exotic**	**Mixed**	**Native**	
Canopy % of total stream length	50%		25%	11%	14%	
length of stream (m)	89,436		45,419	20,275	24,762	
Understorey % of total stream length	30%		20%	38%	12%	
length of stream (m)	53,569		36,682	68,771	20,871	
Groundcover % of total stream length	1%		81%	14%	4%	
length of stream (m)	1,716		144,563	25,944	7,230	
Dominant Vegetation Type	**Grassed**	**Planted**	**Low Growing**	**Scrub**	**Regenerating**	**Mature**
% of total stream length	46%	6%	9%	23%	9%	7%
length of stream (m)	82,439	10,553	16,774	41,242	15,497	13,387
Instream Vegetation	**None**		**<20%**	**20-50%**	**>50%**	
Emergent Macrophytes % of total stream length	20%		38%	14%	28%	
length of stream (m)	17940		34257	12628	25122	
Submerged Macrophytes % of total stream length	42%		44%	10%	4%	
length of stream (m)	38173		39965	8554	3255	
Green Filamentous Periphyton % of total stream length	85%		9%	4%	2%	
length of stream (m)	76249		8227	3787	1683	
Other Periphyton % of total stream length	83%		6%	5%	7%	
length of stream (m)	74358		5290	4448	5850	

Note that Average Riparian Width, Vegetation Height Categories, and Dominant Vegetation Type are assessed for each bank separately, so the sum total length will be twice the total stream length surveyed.

Emergent macrophytes, mainly comprising willow weed, water celery and watercress, were widespread across the majority of tributaries within the catchment, being recorded in 80% of streams. Dense stands of these macrophytes are common in areas where low channel shading, high nutrient loadings and soft sediment substrate combine to provide ideal conditions for the proliferation of these plants.

Submerged macrophytes, composed almost entirely of the aquatic weed *Egeria densa*, are also common within the deeper stream channels, being found in 58% of streams. Large beds of *Egeria* are present along much of the main stem of the Ngakoroa Stream downstream of NGA_MAIN_23 and make up a significant proportion of the in-stream habitat in this area. This weed was also common in many of the online ponds throughout the catchment, such as those within the NGAWEST tributary. This included the online dam on NGAWEST_6, which had surface-reaching beds of *Egeria* covering the entirety of the 4 ha lake.

Another submerged macrophyte present in the Ngakoroa catchment is hornwort (*Ceratophyllum demersum*), an exotic species that is classified as a surveillance pest plant under Auckland Council's Regional Pest Management Strategy. Hornwort was found along NGAWEST_7 and formed surface-reaching mats.

Periphyton is the algae found growing on the bed of streams. It plays a key role in streams by turning dissolved nutrients into food for invertebrates that are themselves food for fish and birds. This group of organisms is essential for ecosystem functioning, but in certain circumstances they can proliferate, causing issues such as the degradation of aesthetic, recreational and biodiversity values. However, extensive filamentous algae may also negatively impact native fish and invertebrates as habitat is altered and becomes less suitable. Periphyton blooms are typically the result of a combination of factors including high light levels, high nutrient inputs, the disturbance regime of the stream, ambient temperatures.

One third of the stream length within the Ngakoroa catchment had periphyton present, with green filamentous periphyton recorded over 15% of the total stream length. Periphyton levels tend to be relatively low however, with only 9% of streams having periphyton covering greater than 50% of the stream substrate. There was no specific pattern to the location of stream reaches containing high levels of periphyton coverage, although most were found in smaller first and second-order tributaries.

4.1.4 Habitat

The majority of habitat types within each reach were runs, followed by pools and riffles. In-stream habitats within the catchment tend to be homogenous, with 58% of stream reaches containing only runs, and an average of 1.7 habitat types per reach. Only 5% of reaches have more than three habitat types present, indicating that in-stream habitat structure suitable for a variety of aquatic fauna and flora is largely lacking at a catchment scale.

Only 4.8% of stream reaches contained suitable potential in-stream spawning sites. In-stream spawning habitat requires the presence of hard substrates such as boulders and large cobble that fish can lay their eggs on, so the rarity of this type of habitat within a catchment dominated by soft-bottomed streams is unsurprising. The majority of this type of habitat was located along reaches of the main stem of the Ngakoroa Stream between NGA_MAIN_24 and NGA_MAIN_32 within Management Zone 8 (Section 3.1.10), however the presence of downstream barriers to swimming fish species means that this habitat is likely to be utilised for spawning only by non-migratory native species such as Cran's bully.

Bankside habitat suitable for fish spawning was relatively uncommon as well, being present on only 6.9% of reaches. Within the Ngakoroa catchment, these areas of potential bank spawning habitat were all located well above the tidal interface and therefore did not apply to inanga, which only spawn amongst bankside vegetation in the lower reaches of streams in the vicinity of the saline wedge. This does not include the area identified in Section 4.5 as potential inanga spawning habitat, as it was located downstream of the first reach assessed.

Native galaxiid species such as banded kokopu spawn further upstream and require a low bank gradient, good connectivity between the stream channel and floodplain, a deep layer of leaf litter and good canopy cover above in order to lay their eggs. These conditions are generally only found in the forested upper reaches of

first-order tributaries, most of which are in the NGAWEST and TRIB17 areas highlighted in Management Zone 7 (Section 3.1.9).

Stable undercut banks provide important in-stream habitat for fish, especially in soft-bottomed streams that lack the habitat complexity that is present in hard-bottomed streams with a boulder or cobble substrate. This habitat type was very rare within the Ngakoroa catchment, with over 89% of the total stream length having no undercut bank habitat at all, and only 1.3% of the total stream length showing either good or extensive stable undercutting. The lack of undercut bank is unsurprising given the widespread extent of channel modification, stock damage and lack of significant riparian vegetation throughout much of the catchment.

Table 14: Summary of watercourse habitat diversity

Attribute	**Mean**		**Min**		**Max**
Number of Habitat Types within reach	1.7		1		5
Fish Spawning Habitat present	**In stream**		**Bank**		**In stream & Bank**
Percentage of Reaches	4.8%		6.9%		0.2%
Stable Bank Undercutting	**None**	**Some**	**Moderate**	**Good**	**Extensive**
% of total stream length assessed	89.7%	6.8%	2.2%	1.1%	0.2%
length of stream (m)	71,025	5,420	1,774	836	167

Note that for bank undercutting the categories are defined by a percentage of the total reach length with undercutting present i.e. if there are 500m of reach with 'Good' undercutting then <50% of this total length is undercut. Refer to the methodology document for further details. Reaches that have only undergone desktop assessments have been excluded from these statistics.

4.2 Natural Structures

There were a total of 50 natural structures recorded in the Ngakoroa catchment, consisting of 17 waterfalls and 33 cascades. The average width of waterfalls was 4.9 m and 2.8 m for cascades. The cascades were on average 7.8 m long, with the longest being a series of four smaller cascades over a distance of 60 m (NGAWEST_14). The greatest drop height from a waterfall was 10 m (TRIB17_1), but on average the drop height was 2.6 m. Forty of the natural structures were recorded as having high levels of turbulence (23 cascades and 17 waterfalls), while four cascades (TRIB32_9, NGA_MAIN_66, TRIB27_13, NGAWEST_56) and 10 waterfalls were recorded as having very high water velocities at the time of survey.

A cluster of seven cascades and five waterfalls were located along a 3.7 km stretch of the main stem of the Ngakoroa Stream from NGA_MAIN_22 to NGA_MAIN_33, the majority of which falls within Management Zone 8 (Section 3.1.10). The cascades vary between 0.5 and 20 m in length and 0.3 to 2 m in height, while the waterfalls are between 2.5 and 7 m high.

One of the largest waterfalls within the Ngakoroa catchment is located in this section in a very steep part of the gully on reach NGA_MAIN_29, and has been formed where the stream flows over the edge of a massive overhanging bedrock slab that extends the full width of the gully (Figure 13).

A large cascade sequence is located approximately 1.1 km downstream on NGA_MAIN_24 and is associated with deep plunge pools that have been carved out of the bedrock (Figure 13).

The lower section of TRIB17 also has a high concentration of significant natural structures, with three waterfalls and two cascades within a distance of 0.8 km. One of these waterfalls is located on TRIB17_70, near the confluence with the main stem of the Ngakoroa Stream, and is also associated with a large bedrock slab that has become undercut (Figure 14).

The largest waterfall in the Ngakoroa catchment, estimated at 10 m in height, is located 0.5 km further upstream at TRIB17_1 (Figure 14).

Figure 13: Waterfall flowing over bedrock slab, approx. 7 m in height, on NGA_MAIN_29 (left) and large cascade sequence on NGA_MAIN_24 (right)

Figure 14: Waterfall, approx. 7m high, on TRIB17_70 (left) and approx. 10m high waterfall on TRIB17_1 (right)

Table 15: Natural structure safety risk matrix for structures recorded as 'Not safe' and 'Not safe, Drop >1.5m'				
Total number of natural structures			**50**	
Attribute			**Access to Structure**	
Not safe		**Easy**	**Moderate**	**Difficult**
Land Ownership	Public	-	-	-
	Private	-	-	-
Not safe, Drop >1.5m		**Easy**	**Moderate**	**Difficult**
Land Ownership	Public	-	-	-
	Private	-	9	11

4.3 Fish Survey

A total of eight species of native fish (inanga, banded kokopu, common bully, Crans bully, redfin bully, common smelt, shortfin and longfin eel), four species of exotic fish (koi carp, mosquitofish, grass carp and silver carp), plus the native freshwater crayfish koura (*Paranephrops planifrons*) have been recorded from the Ngakoroa catchment.

These records included incidental observations undertaken while assessing stream assessments, together with existing data recorded in the NZ Freshwater Fish Database.

Direct comparison and quantitative measures of fish populations are not possible from these data sources, as a range of sampling techniques have been used, ranging from estimated abundance to direct counts. As a consequence, fish distribution in the catchment is indicative only.

4.3.1 Native Fish Distribution

Inanga (*Galaxias maculatus*), are typically considered to be poor climbers and are therefore unable to migrate past even moderate natural or artificial in-stream barriers, such as cascades, weirs or waterfalls. For this reason they are usually restricted to low-gradient reaches within catchments that are relatively close to the coast.

Schools of inanga were observed in the main stem of the Ngakoroa Stream as far upstream as NGA_MAIN_18, which is approximately 6 km from where the stream discharges into Drury Creek and around 0.5 km below the first notable barrier to fish passage; a natural cascade formed by multiple trees having fallen across the main stream channel. This indicates that, at least within the main stem of the Ngakoroa Stream, inanga appear to be able to utilise the full extent of the available habitat unencumbered by artificial barriers to fish passage.

An NZFFD record from 1991 records inanga being found as far upstream as NGA_MAIN_46. Given that there are at least thirteen natural structures located downstream of this point that would act as barriers to swimming fish species, this record appears to be erroneous.

Banded kokopu (*Galaxias fasciatus*) were captured on three occasions while undertaking stream assessments. Two of these were within the forested headwaters of TRIB16, with one fish being found in a similar position within the catchment in the neighbouring TRIB15. Records of this species from the NZFFD are sparse, with two records also recorded in a similar mid-catchment position, with the furthest upstream record being at NGA_MAIN_46.

Both longfin and shortfin eels (*Anguilla dieffenbachii* and *Anguilla australis*, respectively) were recorded throughout the catchment, indicating that they were able to successfully negotiate many natural and artificial in-stream barriers present.

One freshwater crayfish (koura) (*Paranephrops planifrons*) was also found in TRIB17_9, which was located within Ravensthorpe Scenic Reserve.

The NZFFD also had records within the catchment for common bully (*Gobiomorphus cotidianus*), Cran's bully (*Gobiomorphus basalis*), redfin bully (*Gobiomorphus huttoni*) and common smelt (*Retropinna retropinna*). The record for common smelt appears to be spurious however, due to its location in the upper catchment far upstream of where this species would be expected to inhabit. However, as there are only 25 NZFFD records for the whole Ngakoroa catchment, with the most recent being from 2001, their value in assessing the fish populations currently present is limited.

4.3.2 Exotic Fish Distribution

Koi carp (*Cyprinus carpio*) were observed in two general locations within the catchment. The first was within the main stem of the Ngakoroa stream in the lower third of the catchment where the channel was wide, deep and soft-bottomed. In these sections small schools of koi where observed cruising and feeding in the shallows. The second main area was in the vicinity of the large artificial pond just off Mill Rd in Bombay. This pond is a known location for coarse fishing, where anglers target exotic species such as koi, so the presence of this species within the pond itself and nearby streams is unsurprising as they will have been introduced to this area in the past.

Two koi carp were also observed within an ornamental pond on a lifestyle block on Runciman Rd in Ramarama. Given the isolated location of this pond, it is highly likely that these fish were intentionally released there by the landowner.

Mosquitofish (*Gambusia affinis*) were present in high numbers throughout the entire catchment. Because mosquitofish are an invasive exotic species that is able to thrive in shallow, highly-modified watercourses, the high number of artificial ponds and macrophyte-clogged streams present throughout the Ngakoroa catchment provide habitats that are much better suited to this species than to most native fish, which prefer streams with high riparian cover and lower water temperatures.

Both koi carp and mosquitofish are designated as pest fish under Auckland Council's Regional Pest Management Strategy. Koi are known to degrade water quality due to resuspension of fine sediment through their feeding activity, while mosquitofish compete with juvenile native fish for food resources.

Due to the existence of significant natural barriers to fish passage within the mid-reaches of the Ngakoroa Stream (see section 4.3.3), the spread of both koi and mosquitofish throughout the catchment will be due to human-assisted translocation.

Other exotic species recorded in the NZFFD include grass carp (*Ctenopharyngodon idella*) and silver carp (*Hypophthalmichthys molitrix*). Both of these species are used for biological control, of aquatic vegetation and suspended algae respectively, and their introduction to new waterways is strictly regulated.

Grass carp were recorded from two ponds, one in the vicinity of NGA_MAIN_61 and the other near NGA_MAIN_36, which also contained silver carp. As both of these records are from 1997 and these fish are unable to breed in NZ conditions, it is not known if there are any still present in the catchment.

4.3.3 Barriers to Fish Passage

Barriers to fish passage can severely limit native fish populations by restricting the amount of stream habitat that they can access. This is because many native species complete their larval life-stage in the marine environment before migrating into freshwater catchments as juveniles, where they continue to develop into adults once they are established in suitable upstream habitats.

Artificial barriers to fish passage are present throughout the Ngakoroa catchment and include dams, perched culverts, fords, weirs and online ponds. Natural in-stream structures, such as cascades, waterfalls and debris dams, can also act as barriers to fish passage.

The degree of impact of a barrier on particular native fish species is largely due to their locomotor ability. This results in species such as inanga, which can only employ 'burst swimming' to get past in-stream barriers, being restricted by structures that would be passable by species that are able to climb using the wetted margins on each side of structures, such as banded kokopu or eels.

All barriers to fish passage were classified into one of three categories (Swimmer, Climber or Anguilliform) according to the locomotory function of the fish that were likely to impede. Barriers to swimmers will affect species that are only capable of swimming (e.g. inanga, common bully), while barriers to climbers will also prevent species such as banded kokopu and redfin bully from migrating upstream. The most difficult instream barriers will also affect anguilliformes (adult eels), which are capable of traversing short distances across land between waterbodies.

A total of 13 cascades were recorded as complete barriers to swimming fish species, with the furthest downstream being located on NGAWEST_56 and the furthest upstream on NGA_MAIN_66.

Only one waterfall, located on TRIB17_70, was assessed as a complete barrier to all fish species, due to it flowing over an overhanging bedrock slab (see Figure 14). Despite this there are records of shortfin and longfin eels upstream on TRIB17_42, TRIB17_56 and TRIB17_57, so some must still be able to negotiate this obstacle when migrating upstream (see Map 6, Appendix 1).

Artificial barriers to fish passage are absent from the main stem of the Ngakoroa Stream below NGA_MAIN_58, where the Auckland Council flow monitoring weir is located, however a series of natural barriers consisting of seven cascades and five waterfalls exists over a 3.7 km length of stream located in the mid-catchment between NGA_MAIN_22 and NGA_MAIN_34.

These natural barriers effectively restrict swimming species to below reach NGA_MAIN_22, while the large number of barriers and the size of some of the waterfalls over this stretch are also likely to reduce the numbers of climbing species that are able to venture further upstream.

Despite the lack of artificial barriers present within the main stem of the Ngakoroa Stream, almost all tributaries contain multiple barriers, many of which are culverts associated with online farm ponds and stock crossings. An example of this is the series of online ponds above NGAWEST_53, where eight culverts that have been assessed as complete barriers to fish passage are present over approximately 800 m of watercourse.

Two of the most significant barriers to fish passage within the Ngakoroa catchment are the perched culverts located on NGAWEST_7. These two structures (Asset IDs: NGAF_137 & NGAF_142) are outlets for the dam that has created a large 1.1 ha online pond immediately upstream on NGAWEST_62 (Figure 15). These culverts are perched by 0.8 and 1.5 m respectively, presenting a complete barrier to for all fish species. The effect of these culverts is to restrict fish from accessing a large proportion of the NGAWEST tributary, particularly to the high-quality fish habitat located in headwater native forest reaches on NGAWEST_24 and NGAWEST_27 (see Section 3.1.9).

Figure 15: Perched culverts forming significant fish barriers on NGAWEST tributary. Asset ID NGAF_137 (left) and NGAF_142 (right).

Land development within the Ngakoroa catchment provides opportunities to remove or remediate artificial barriers and to ensure that designs for future in-stream structures provide for the unimpeded migration of native fish species.

This is particularly relevant for barriers that are found within the FUZ, as these areas will be undergoing large-scale development which offers an increased scope to remedy identified fish passage issues during the development process.

Priority barriers for remediation within the FUZ include the following:

- The perched culvert and its outlet structure (Asset IDs NGAPR_065 and NGA_139 respectively) which are located on NGA_TRIB3_4;
- A culvert located on PAH_MAIN_5 (Asset ID: NGAP_048), which is perched by 0.3 m;
- A perched PVC pipe (Asset ID: NGAP_050) located on PAH_TRIB2_2. This barrier is also within EO04 (Section 6.0).

A summary of the fish passage barriers by type can be found in Table . By definition, all of the Natural Structures recorded are barriers to at least swimming species, while 8% of Inlets/Outlets and 34% of Culverts/Pipes were found to restrict swimming species. Of the 398 culverts and pipes recorded throughout the catchment, 26% are acting as barriers to climbing species as well. This indicates that this class of engineering asset presents the largest number and proportion of significant barriers to fish passage within the Ngakoroa catchment.

Table 16: Fish passage and habitat features within the catchment

Fish Barriers	Natural Structures	Engineering Assets (inlets and outlets)	Engineering Assets (culverts and pipes)
Fish Passage devices present	N/A	0	0
Barrier to Swimmers	50	21	134
Barrier to Climbers	7	12	105
Barrier to Anguilliformes	3	2	55

Note that barriers to swimmers, climbers and anguilliformes are not additive, e.g. of 50 natural barriers to swimmers, 7 of these are also barriers to climbers and 3 are barriers to anguilliformes.

TRIB17 contains more than a dozen artificial in-stream structures that will restrict the ability of native fish to access the upper reaches of headwater streams, a number of which contain largely intact native riparian vegetation and potential spawning habitat. However, the presence of a 7 metre-high overhanging waterfall on TRIB17_70, near the confluence with the main stem of the Ngakoroa Stream, means that fish passage throughout this part of the catchment is naturally restricted.

Despite a number of eels being recorded upstream of this waterfall, the presence of this structure is likely to act as the main impediment to native fish migration, and therefore remediation of artificial barriers upstream of it should be seen as a lower priority than in other tributaries where such a large downstream natural barrier does not exist.

4.4 Stream Mouth

The Ngakoroa catchment drains into the Pahurehure Inlet, which flows into the Manukau Harbour. The upper boundary of the stream mouth was dominated by the native wetland species raupō, with the sedge family *Bolboschoenus* also dominant on both banks (Figure 16). The low-gradient (<10° slope) stream banks and dense ground cover on both banks was noted as suitable spawning habitat for the native freshwater fish inanga. Due to the large extent of the Pahurehure Inlet, the lower boundary of the stream mouth was not assessed.

The Ngakoroa stream mouth was recorded as a low-energy environment. Sediment load modelling by Green (2008), indicated that sediment loads are largely deposited within these low energy 'settling zones' in the upper sections of the Ngakoroa stream mouth. In combination with the nearby Slippery Creek catchment, the Ngakoroa catchment is the primary source of sediment to the harbour (approximately contributing 65% of total) (Green, 2008). These values have the potential to increase with future urban development proposed in the catchment.

Figure 16: The Ngakoroa catchment stream mouth, note the raupō wetland in the right upper corner.

4.5 Inanga Spawning

One potential inanga spawning area was located near the mouth of the Ngakoroa Stream on the true left bank (NGA_MAIN_1). The spawning area identified is 0.85 ha in size with a low bank gradient, and is currently in a pasture (Figure 17). Due to its position at the bottom of the catchment and the flat topography of the area, this site is able to be inundated by spring tides, which are a critical component in inanga spawning. The site has therefore been identified as having potential for enhancement to improve its potential as an inanga spawning location (see Enhancement Opportunity EO03 in Section 6.0).

Figure 17: Potential inanga spawning area in a pasture area adjacent to the Ngakoroa Stream (NGA_MAIN_1) with potential for enhancement.

4.6 Wetlands

A total of 457 wetlands are present throughout the Ngakoroa catchment, of which 89% were assessed in the field. The remaining 49 wetlands were unable to be accessed and were assessed via desktop using aerial images only.

A summary of the variety of wetland types , natural and artificial, and dominant vegetation is provided in Figure 18. Refer to Map 5, Appendix 1 for the map of identified wetlands.

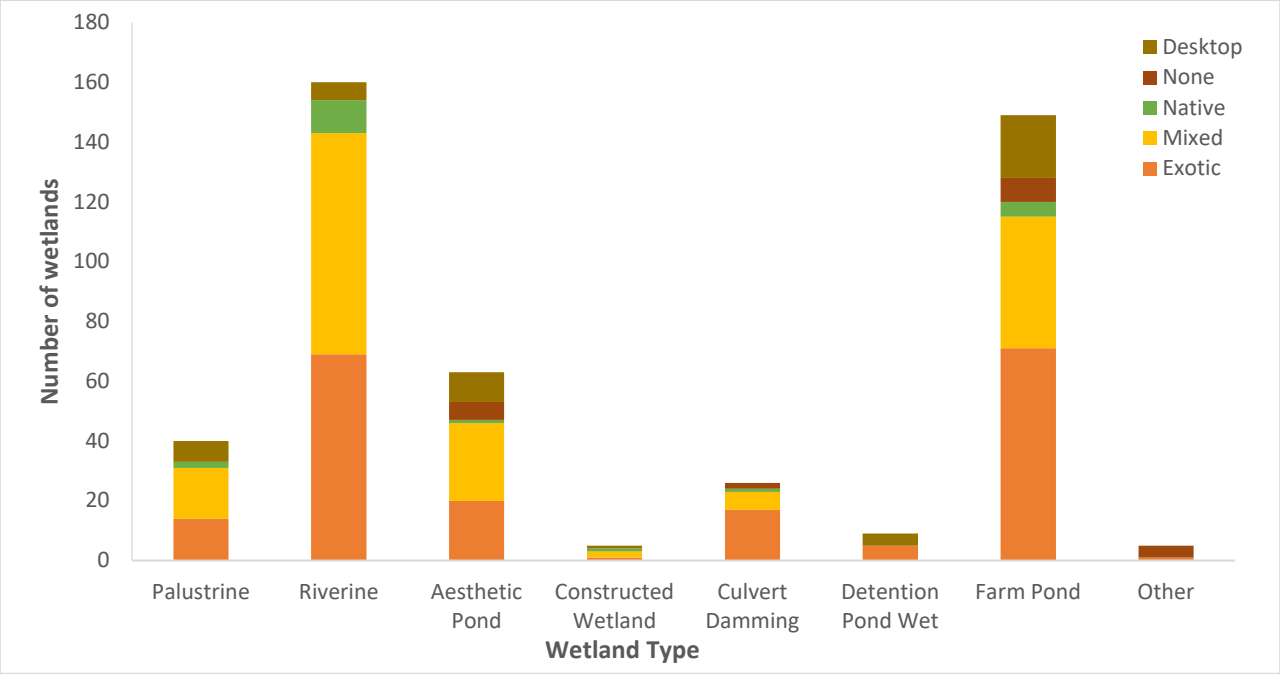


Figure 18: Summary of wetlands in the Ngakoroa catchment

4.6.1 Artificial Wetlands

The most common type of artificial wetland in the catchment are ponds used primarily for stock watering or irrigation purposes (farm ponds), which make up a third of the total number of wetlands. These are typically small, with an average surface area of approximately 1356 m^2, and range from 9 m2 to 15,171 m^2 in size.

Farm ponds, a large number of which are online, are scattered throughout the catchment. The largest of these are located in the middle of a market gardening area on TRIB11, and are used primarily for crop irrigation purposes.

Aesthetic ponds, which comprise 14% of all wetlands, are also common and range in size from 74 m^2 to 12,200 m^2, with an average size of 1524 m^2. These are commonly associated with lifestyle blocks and often contained aquatic ornamental plant species such as waterlilies.

Koi carp, an exotic pest fish, were recorded in some aesthetic ponds, including a large pond located just off Mill Rd, Bombay on TRIB27_16, which is known to have been stocked with exotic fish for coarse angling purposes, and also a smaller pond on TRIB14_6 (see Section 4.3.2).

The largest of the artificial wetlands within the catchment are two online dams located on the Ngakoroa West tributary. The larger of these dams is located on NGAWEST_6, is over 4 ha in size and the type was classified as 'Other'. According to the landowner, he is currently dealing with Auckland Council Compliance regarding the dam that he constructed, so it appears that this wetland is possibly unconsented.

The smaller dam, located at NGAWEST_62, is 1.1 ha in size and was classified as a 'Constructed Wetland'. It has a camouflaged hide present suggesting its primary use is for duck shooting.

The two dams both contained excessive submerged macrophyte growth, with surface-reaching beds of *Egeria densa* covering the entire area. The amount of these plants suggests that they will have significant effects on the dissolved oxygen levels present within the water column of both dams, especially during the night when the plant matter will absorb oxygen, resulting in very low concentrations.

Online farm ponds, dams and aesthetic ponds can contribute to negative environmental impacts within the catchment, such as their outlets presenting potential barriers to fish passage; reduced dissolved oxygen levels due to excessive aquatic weed growth; thermal stratification and discharge of higher temperature water; increased flooding risk to downstream properties; and the provision of ideal habitat for pest plants and fish to colonise.

Figure 19: Large online dam at NGAWEST_6 (left) and typical farm pond, NGA_TRIB6_1 (right)

4.6.2 Natural Wetlands

Natural wetlands are those that would have occurred naturally as a consequence of the surrounding topography or geographical features in the area, and were not created by man. These wetlands may be modified from their natural state by vegetation removal, introduction of exotic species, modification of banks, drainage and altered flow due to catchment development.

Eighty percent of the natural wetlands in the Ngakoroa catchment are riverine, with the remainder being palustrine. Most of the riverine wetlands are associated with the headwaters of first order streams or floodplains in the lower areas of the catchment. A number of wetlands have evidence of cattle damage, with heavy pugging common in unfenced wetlands within farm paddocks. In some cases channels that would naturally have been streams with defined banks have become so badly pugged that the normal channel morphology and bank structure has been destroyed, to the extent that they currently exhibit primarily wetland features (Figure 20).

Natural wetlands dominated by native vegetation are rare, making up only 7% of the total number, while those with exotic or mixed vegetation types make up 42% and 46% respectively. The remainder were assessed via desktop only, and therefore their vegetation type could not be accurately determined.

Exotic weed species, such as willow weed, water celery and mercer grass, were the dominant vegetation types for the majority of natural wetlands. Other common species present included juncus, sedges, willows and manuka.

One of the larger natural wetlands is a large pond on TRIB17_41, where a duck-shooting hide has been constructed and a small area of riparian vegetation cut down to provide a clear field of fire for hunters (Figure 20).

Figure 20**: Riverine wetland created by severe cattle pugging on TRIB14_6 (left). Large pond surrounded by willows, raupo and sedges on TRIB17_41 (right).**

4.7 Engineering Assets

Information about the condition, function and location of engineered stormwater assets is required to manage them effectively.

Engineering asset inlet and outlet points were surveyed within the existing and future urban zones and at all public roads and associated with the rail line. Across the remainder of the catchment, not zoned for future urban development, only pipe/culvert points were recorded. For details of these rural structures, the geodatabase should be referred to.

Assets within the future urban area are prefixed with an asset ID NGA_XXX whilst assets associated with road and rail infrastructure are prefixed with asset ID NGAR_XXX. Where assets are recorded in Council GIS the SAP ID is referred to.

Of the 277 assets surveyed, 229 assets were fully assessed. Of these assets:

- 144 were inlets or outlets, with no headwall, wingwall, or dissipating structures;
- 7 were inlets or outlets, with no headwall, wingwall but had some type of dissipating structure; and,
- 78 were inlets or outlets with headwall, wingwall and dissipating structures.

The remaining 48 assets included one that was identified from Auckland Council GIS but was not located in the field and 47 assets that could not be accessed or located due to heavy vegetation or other constraint.

A full summary of maintenance works is provided in Appendix 2. Refer to Map 4 in Appendix 1 for an overview of asset locations and erosion issues.

Table 17: Summary of engineering assets (inlets and outlets) and significant issues and remedial actions

	Assets Surveyed	Assets Correct in GIS	Assets Incorrect in GIS	Assets Not in GIS
Number of assets (inlets/outlets)	277	4	1	224

Condition Assessment*	**Very Good**	**Good**	**Average**	**Poor**	**Very Poor**
Condition of structure	2	35	24	14	3

Erosion Assessment	**None**	**Slight**	**Moderate**	**Severe**
Extent of erosion	202	40	28	4

Maintenance Assessment	**Replacement**	**Structural**	**Patching**	**Debris Removal**	**Vegetation Clearance**	**Erosion Protection**
Maintenance required	12	12	3	12	24	28

** The condition of the remainder of the assets (n=199) were recorded as "Does Not Apply"*

4.7.1 Council Infrastructure

There is minimal Council owned SW infrastructure recorded in GIS within this catchment. This infrastructure is associated with the recent developments in the vicinity of the intersection of Bombay and Paparata Roads. Erosion protection maintenance is recommended for two of these structures associated with displacement of rock rip rap at Bombay Rd (ID 3000039153) and protection of the channel downstream of bubble up chambers at Christa Place (ID 2000322225) (Figure 21). It is also noted that the wetland upstream of the Bombay Rd outlet was essentially dry at the time of survey, however high velocity flow was discharging from the outlet.

Figure 21: Left - Bombay Rd (ID 3000039153). Right - Christa Place (ID 2000322225)

4.7.2 Public Infrastructure

Within the same development area, public infrastructure at 180 Bombay Rd (associated with inlet for pipe (2000200812, not recorded in GIS) was in poor condition with moderate erosion issues associated with roadside drainage, broken poured *in situ* concrete erosion protection structures, and a broken grille over a catch pit to a 1.7 m drop (assets NGAR_105,106,107,073) (Figure 22). The outlet pipe to this structure was also in very poor condition (NGAPR_052).

Three other assets associated with public roads were in poor to very poor condition, these were all located within the future urban area.

Potential flooding issues were recorded for twelve other assets associated with road corridors. This included:

- The intersection of McPherson and Burtt Rd (Future urban) where the road culverts appear to be buried and broken (NGAPR_053) however moderate to severe erosion issues were also observed resulting in exposed cables (Figure 23).
- Inlets and outlets associated with a culvert and roadside drains at Beaver Rd where this had slumped and was partially obstructed with fine sediment.
  An inlet to a culvert Norfolk King Drive (NGAR_084) was noted to be submerged presenting a risk of flooding and subsequent damage of the road; and,
- The inlet under SH1 due to dense obstruction of gorse (NGAR_001).

Figure 22: Left – Middle of roadside infrastructure showing pipe NGAPR_052 draining towards broken catchpit grill with inlet to Council pipe 2000200812 under this grill. Concrete reinforcing for additional outlets to the left and right. Right – facing upstream showing broken concrete dissipation.

Figure 23: Left – Evidence of flooding in road corridor at Burtt Rd McPherson Rd intersection. Right – Moderate erosion at outlet NGAR_074 at McPherson Rd resulting in exposed underground services

Figure 24: Left - Inlet (NGAR_047) and Right - outlet (NGAR_067) at Beaver Rd

4.7.3 Private Infrastructure

Private inlet/outlet points were assessed only within the future urban area. The most common structures were associated with farm tracks where crossing retaining beams typically served double function as headwall structures. Erosion and damage of these structures was common, associated with age and lack of maintenance, as well as cattle damage (e.g. Figure 25). The greatest number of assets requiring maintenance actions were located on Tributaries 3 and 8.

It is recommended that all structures in poor or very poor condition, or associated with moderate to severe erosion are repaired or replaced with new structures specifically designed for purpose at each of these locations or alternatively, it is anticipated that with increasing development in the area and reduced need for vehicle access across streams, many of these assets can be removed. Immediate action to remediate these issues will prevent further degradation of their associated streams.

Flooding risks were also recorded at 11 private inlet or outlets typically associated with risk to private driveways. Flood risk to non-habitable floors was also noted at NGA_TRIB8_6 at 763 Runciman Rd.

Figure 25: Erosion at outlet NGA_064 with partial collapse of retaining beams for crossing

4.7.4 Safety Issues

Thirty-nine potential safety issues associated with inlet or outlets, across both public and private land uses, were identified. These were predominantly due to the vertical drop height from the top of the structure exceeding 1.5 m, either without the presence of a safety fence or barrier to restrict access, or that an existing safety fence is damaged and in need of repairs. No safety issues were recorded for Council-owned infrastructure.

The majority of safety issues on public land were associated with unprotected drops from assets in rural road corridors. These may present a risk to contractors conducting maintenance activities or to pedestrians walking in the road corridor. It is recommended that asset ownership between roading authorities is clarified in respect to these structures.

Safety issues recorded on private land were also commonly associated with unprotected drops from stream crossings on farms.

Of the six assets on private land that had drops of over 1.5 m and easy access, five were within road corridors and one was in a rail corridor.

Table 18: Engineering structure safety risk matrix for structures (inlets/outlets)

		Access		
Not safe		**Easy**	**Moderate**	**Difficult**
Land Ownership	Public	5	-	3
	Council	-	-	-
	Private	-	9	10
	Unsure	-	-	-
Not safe, Drop >1.5m		**Easy**	**Moderate**	**Difficult**
Land Ownership	Public	8	3	6
	Council	-	-	-
	Private	6	13	1
	Unsure	-	-	-

4.8 Engineering Assets (culverts, pipes)

A full assessment of pipes and culverts was undertaken for assets within the existing and future urban zones (prefix NGAP_XXX) and where associated with public roads and rail (prefix NGAPR_XXX).

Within the remaining rural areas of the catchment, an abridged assessment was undertaken which included the diameter of the culvert or pipe, and any fish passage issues associated with the pipe or culvert or the inlet or outlets of that structure. Refer to the notes fields in the geodatabase for all rural assets for further comment on current erosion or structural issues associated with these private structures. Rural pipe assets are prefixed NGAF_XXX.

Overall 146 assets were fully assessed, with a further 251 abridged, rural assets recorded. A full summary of maintenance works is provided in Appendix 2. Refer to Map 4 in Appendix 1 for an overview of asset locations and erosion issues.

Of the 146 assets, 24 assets were unable to be fully assessed due to access difficulties, or where submerged or otherwise obscured from view. Only five pipes were recorded in Council GIS all of which were correct. No maintenance recommendations were identified for Council owned pipes/culverts.

In addition to culverts NGAPR_051, 052, and 053 highlighted in section 4.7.2 above, NGAPR_044 under Great South Rd was also in poor condition with displaced joints and exposed rebar (at the Kern Rd intersection) (Figure 26). Erosion and discharge issues were also raised downstream of this culvert, and the adjacent tributary. A privately owned pipe from a commercial horticultural area on the TLB of TRIB11_23 was also noted as discharging a large quantity of rock rip rap and sediment to the stream (Figure 26).

Numerous issues were also noted for privately owned rural culverts outside of the future urban area. It was out of scope to assess condition and maintenance recommendations for these structures, however one potentially significant issue was identified associated with an unconsented online dam structure located on NGAWEST_6. The dam had flooded the upstream gully to a total area of approximately 4 ha, and was constructed to provide access to a cleanfill site servicing heavy traffic (anecdotally up to 20 trucks/day). The main discharge outlet of this pipe was displaced, with high flow discharging through holes and cracks in the wall of the culvert (Figure 26). It is understood that the landowner is currently working with Auckland Council Compliance regarding the management of this dam.

Approximately 500 m upstream at NGAWEST_62, another large (1.1 ha) online pond was observed with a significant breach on the true left of the dam face. It appears that a high water bypass channel had been dug along the top of the dam leading to the large erosion hotspot, with a drop of >3 m high. The main outlet discharge points (NGAF_137, NGAF_142) were perched 0.8 m and 1.5 m above the stream bed with willow buttressing providing some stability of the banks, however significant erosion and sediment deposition was observed immediately downstream of this dam.

These dam structures are also featured in Sections 4.3.3, 4.6.1, and 4.10, which address barriers to fish passage, artificial wetlands and erosion hotspots, respectively.

Figure 26: Left - Culvert NGAPR_044 at Great South Rd; Right - discharge of rock rip rap at Trib11_23 (NGA_155)

Figure 27: Culvert at online dam (NGAF_114)

Figure 28: Dam wall breach

Table 19: Summary of engineering assets (culverts and pipes) and significant issues and remedial actions.

	Assets Surveyed	Assets Correct in GIS	Assets Incorrect in GIS	Assets Not in GIS
Number of Assets (pipes/culverts)	397 (146 full assessment)	5	0	315 (50 public infrastructure)

Condition Assessment	**Very Good**	**Good**	**Average**	**Poor**	**Very Poor**
Condition of assets	3	91	19	14	2

Maintenance Assessment	**Replacement**	**Structural**	**Patching**	**Debris Removal**	**Vegetation Clearance**	**Erosion Protection**
Maintenance required	17	4	2	7	4	6

4.9 Bank and Channel Lining

Five stream reaches in the Ngakoroa catchment had bank lining totaling 124 m (Table 20). There was no channel lining recorded along the survey reaches. The bank lining recorded was either made from timber or rocks and access to all sites was either moderate or easy. Three sites were recorded as being Not Safe – Drop 1.5 m, these were on NGA_MAIN_3, NGA_TRB9a_1 and NGATRIB4_6. The bank lining on NGA_MAIN_3 is on public land. None of the bank lining assets were recorded as having a significant impact on stormwater flows. The private asset recorded in poor condition on NGAWEST_58 was a timber retaining structure that was falling into the stream and causing erosion on the TLB, it also was recorded as being Not Safe, with a 1.5 m drop.

Figure 29: Rock bank lining along NGA_MAIN_2, which appeared safe and had easy access.

Table 20: Summary of bank lining assessed over the surveyed extent.					
Physical Factors					
Total Length of Surveyed Watercourse (m)			89,946		
No. Reaches			497		
Total Length of Bank Lining (m)			124		
Total Length of Channel Lining (m)			0		
	Mean		**Min**		**Max**
Bank Height (m)	1.7		1		3
Length of bank lining (m)	25		4		50
Length of channel lining (m)	0		0		0
Condition Assessment	**Very Good**	**Good**	**Average**	**Poor**	**Very Poor**
Condition of bank lining % of total bank lining length	0	40	40	20	0
length of lining (m)	0	60	60	4	0
Condition of channel lining % of total channel lining length	-	-	-	-	-
length of lining (m)	-	-	-	-	-
Impact on Stormwater Flows	**Not Significant**		**Significant**		**Critical**
% of total bank and channel lining	100		0		0

Note that the condition assessment is based on the overall condition of the lining, where both banks or channels are lined these are not assessed separately.

4.10 Erosion Hotspots

An erosion hotspot is defined as:

- Severe erosion located within the channel and/or lower or upper banks resulting in slumping and/or exposed soil surfaces.
- The hotspot must also:

i. exceed two metres in length and/or have a total surface area of disturbed soil >5 m^2; and,
ii. be actively eroding; and,
iii. be detrimental to stream health and/or causing significant and/or immediate safety or infrastructure concerns.

There were a total of 24 erosion hotspots recorded in the Ngakoroa catchment (Table 21). Eight hotspots were recorded as having a low residual risk to buildings, the remaining hotspots were assessed as having no discernible risk to buildings.

Thirteen of the erosion hotspots were clustered in the southern area of the catchment within the market gardening area (MZ4; Section 3.1.6). The overall Pfankuch stability index of these 13 hotspots was fair or poor for 11 of the sites, with the other two being classified as good. The sites of erosion at these points was varied, including erosion at waterfalls, culverts and due to collapsed banks . Twelve of these hotspots were recorded as having poor bankside vegetation, a likely correlation with the lack of riparian margins within many of the market gardens in this area.

A significant culvert failure was noted along TRIB24_6, creating an erosion hotspot of 50 m^2 (Figure 30). Three erosion hotspots are associated with this reach (TRIB24_6), which is downstream and adjacent to a market garden and recently developed sub-division.

In the northern part of the catchment, the erosion hotpots are more scattered. Of note are two hotspots on NGAWEST_7 and NGAWEST_5, which are located immediately downstream of the outlets from two large online dams (Figure 32).

Figure 30: Erosion hotspot on NGA_MAIN_22, where slumping on the TLB has occurred as a result of poor bank vegetation and disturbance.

Figure 31: Culvert failure at TRIB24_6 and the associated erosion hotspot along the banks.

Figure 32: Erosion hotspots on NGAWEST_7 (top) and NGAWEST_5 (bottom) associated with large online dams in the Ngakoroa West sub-catchment.

Table 21: Summary of erosion hotspots.

Attribute				
Total Length of Surveyed Watercourse (m)		89,946		
No. Reaches		497		
Total Length of Erosion Hotspots (m)		259		
Total Area of Erosion Hotspots (m^2)		540		
Total Number of Erosion Hotspots		24		
		Mean	**Min**	**Max**
Length (m)		11	4	35
Bank Height (m)		1.6	0.3	3.5
Area (m^2)		24	5	70
Access		**Easy**	**Moderate**	**Difficult**
Land Ownership	Council	1	-	-
	Public	1	-	-
	Private	1	14	7

Table 22: Summary of Pfankuch bank stability assessment of the 10 m upstream of erosion hotspots.

	Excellent	Good	Fair	Poor
Land Slope	20	90	90	40
Mass Wasting	10	70	70	90
Debris Jam	40	150	30	20
Bank Vegetation	0	20	70	150
Overall Stability Index	7	34	27	31
% of total stream length				
length of stream (m)	70	330	260	300

4.11 Miscellaneous Points

A total of 227 miscellaneous points were identified in the surveyed area, covering a range of features, such as debris jams, bridges, pollution, weirs, drainage pipes and weed infestations. Six points were recorded as having a significant impact on stormwater flows.

Refer to Map 8; Appendix 1 for an overview of key miscellaneous features.

4.11.1 Discharges

Thirty-nine discharges were identified within the catchment, 20 of which were tributaries that were identified as discharging into surveyed stream reaches. One spring and three groundwater seepage locations were also identified. Twelve pollution points were identified, of which two concerned the presence of hydrocarbon sheens, three were in regard to sediment runoff and one was because of foam and a large bench of deposited sediment. Three pollution points were associated with dead eels that were found along TRIB_11, although there was no clear evidence of what may have caused the eel deaths (see section 4.1.2). The remaining pollution points were in regard to a decaying animal in the stream at NGA_TRIB8_6, high silt loading and bacterial films at TRIB17_45, and an overflowing water trough creating overland flow down a hill at NGA_TRIB3b_1.

Two discharge points were recorded as having significant impacts on stormwater flows. One of these, located on TRIB24_17, is with regard to a resident who has dug a drainage channel on her property to divert stormwater runoff from an upslope development, while the other concerns road drainage that has been diverted into a property, causing an overland flow path into a pond on TRIB11_18 that appears to be the partial cause of downstream issues.

4.11.2 Engineering

A total of 68 miscellaneous engineering points were identified, 22 of these were stormwater or drainage pipes under 225 mm in diameter and were not identified as having any significant impact on stormwater flows. Eight weirs were recorded, with one on NGA_MAIN_58 being an Auckland Council hydrological monitoring asset (Ngakaroa Flow @ Mill Rd).

Willow trees and their root mats were identified as causing debris jams throughout the catchment. Seven of the 13 debris jams were located in the Future Urban Zone, although none of these were identified as having significant impacts on stormwater flows likely to cause flooding of habitable or non-habitable floors. One debris jam of rock riprap and sediment was recorded as having a significant impact on stormwater flows, this was on TRIB11_23 and was identified as causing damming of upstream flows, and therefore posed a risk of flooding to habitable floors.

Twenty-five other engineering miscellaneous points were identified, which included bubble-up chambers, manholes (a manhole on PAH_MAIN_10 was missing the manhole lid – this was escalated to Auckland Council

immediately as a safety concern), a land bridge, three dams, three pipe bridges, a silt trap, a man-made waterfall on a golf course, and a large spillway constructed of boulders and geotextile located below a large pond.

None of these were recorded as have significant impacts on stormwater flows.

4.11.3 Other

Of the 119 other types of miscellaneous points recorded in the catchment, 58 of these were bridges. The bridges were typically access bridges on farms for stock or for private vehicle movement. Two of these bridges were assessed as having significant risks associated with them. One bridge, located on NGA_TRIB9_1, had pilings on the true right bank exposed due to scour, potentially affecting its structural integrity (see Figure 33 and Table 8), while another bridge on NGA_TRIB8b_1 had the water surface reaching the bottom of the bridge and was recorded as having a significant impact on stormwater flows, as it posed a flooding risk to non-habitable floors (Figure 33).

Figure 33: Bridge on Runciman Rd (TRIB9_1) with exposed piles due to scour (left). Bridge on TRIB8b_1 that poses a flooding risk (right).

Two significant tree points were recorded, which included a number of large puriri (*Vitex lucens)* adjacent to TRIB17_29 and contained within SEA_T_4370, and a large kahikatea (*Dacrycarpus dacrydioides*) by TRIB17_56. These trees were notable for their size and presence within a catchment that tended to lack large native tree specimens.

Five locations were identified as having significant vegetation, which including areas of mature totara (*Podocarpus totara*) and puriri on TRIB17_29; a mixed forest of kahikataea, taraire (*Beilschmiedia tarairi*), karaka (*Corynocarpus laevigatus*) and puriri on TRIB17_44; and a stand of kahikatea, totara and rimu (*Dacrydium cupressinum*) on TRIB11_4 (see Section 4.1.3).

The remaining 54 miscellaneous points classified as 'Other' included a potential swimming hole with access issues, five landslips, one case of litter dumping, seven manmade fords, three areas of weed infestations and two notes on wildlife, namely the presence of deer hoof prints on TRIB17_9 and an infestation of paper wasps on TRIB29_17.

Thirty of these points did not fit into any of the above categories and included features such as overland scour, earthworks, and a concrete overflow channel leading from a pond to the stream at TRIB17_23. Two of these points were recorded as having significant impacts on stormwater flows, with one record on TRIB17_18 being for flood debris found 0.3 m above the road due to a blocked culvert, and the other, located on NGA_TRIB2_2, showing evidence of the road corridor having been flooded, possibly due to a blocked culvert downstream.

5.0 SEV and Additional Variables

5.1 Stream Ecological Valuation Assessment

A total of five Stream Ecological Valuations (SEVs) were performed within the Ngakoroa catchment on the 26th and 27th April 2018. All sites were located in accessible areas and were representative of the variety of land use types within the catchment.

Refer to Map 1, Appendix 1 for an overview of the SEV locations. The full SEV results are provided in Appendix 1.

The five SEV scores ranged from 0.360 to 0.719, which are reflective of 'moderate' overall ecological values.

Future Urban Zone sites (SEV 1, 2 and 3)

Three sites (SEV 1, 2 & 3) were located within the Future Urban Zone in rural land-use areas and all received relatively similar scores; SEV 1 (0.393), SEV 2 (0.483) and SEV 3 (0.482).

SEV 1 was a historically straightened channel with good canopy cover from large exotic trees lining both banks. In-stream channel structure was dominated by large root mats from the trees along the riparian margins, while the substrate consisted of soft clay lumps with only a small amount of sediment deposition.

SEV 2 was located in a farm paddock, and the channel was choked with dense stands of willow weed and the submerged macrophyte *Egeria*. Riparian vegetation consisted of an understory of gorse, with some mature willows along the banks. Access for stock (sheep) to both banks was evident.

SEV 3 contained large stands of willow weed within the channel and gorse along both banks. Extensive stock damage to the stream was evident, with stream banks widened due to erosion and pugging by cattle.

The primary limiting factors for SEV 1 and SEV 2 were in the habitat provision functions, namely spawning habitat for galaxiids and bullies, with a lack of upstream riparian margins also negatively affecting the scores for water quality. SEV 1 also scored poorly for hydraulic functions, due to the modification to the channel through artificial straightening.

SEV 3 had the lowest score for the biogeochemical functions, which was largely due to a lack of riparian canopy vegetation and the extent of modification to the channel caused by cattle damage.

SEV 4

SEV 4 was the only hard-bottomed site sampled, with the land-use immediately surrounding it consisting of residential properties on the true left bank and a road corridor on the true right bank. The riparian vegetation along this reach was predominantly regenerating native forest, which resulted in a high level of shade over the whole length of the reach although the groundcover was dominated by dense *Tradescantia* growth.

Due to the high levels of shade and dense riparian vegetation, the biogeochemical function score for SEV 4 (0.92) was the highest out of the five sites surveyed.

SEV 4 also scored the highest of the five sites for the habitat provision function (0.65), bolstered mainly by the presence of hard-bottomed substrates, including cobbles, boulders and bedrock, that resulted in good scores for bully spawning habitat and the abundance and diversity of in-stream habitat for fish and macroinvertebrates.

Illegal dumping was noted at this site, with discarded car tyres and cardboard found amongst the riparian vegetation. This is likely due to the proximity of Great South Rd, which runs parallel to the true right bank and provides a route for people to undertake illegal fly-tipping at night.

The overall SEV score of 0.719 for this SEV 4 was the highest of the five Ngakoroa SEV sites by a notable margin, with the next highest being SEV 2 with a score of 0.483.

SEV 5

SEV 5 was located adjacent to and downstream of large areas of market-gardening land-use, so the nature of the site was heavily influenced by the horticultural practices in the immediate vicinity. The true right bank was fenced to prevent cattle getting into the stream, while the true left bank was bordered by a large area of market garden.

The stream channel was heavily choked with emergent macrophytes, including willow weed and water celery, and large amounts of loose sediment were present in the channel. A large bench of sediment that extended across the width of the channel was located where a direct flow path from the market garden on the true left bank discharged to the stream (Figure 34).

Figure 34: Looking down market garden flow path towards stream channel, showing sediment benching and excessive macrophyte growth

SEV 5 recorded the lowest overall SEV score of the five sites (0.360). The main limiting factors were the lack of native fish species and a depauperate macroinvertebrate community, which resulted in a very low biodiversity function score of 0.05. The lack of riparian vegetation and large amounts of macrophytes within the stream channel also resulted in a low biogeochemical function score of 0.32.

A thin sheen of hydrocarbon was also observed on the surface of the stream, although the source of it was unable to be determined.

SEV 1

SEV 2

SEV 3

SEV 4

SEV 5

Figure 35: Facing upstream at each SEV site

Table 23: Summary of mean SEV scores across sites.

Site Code	Tributary Code	Hydraulic	Bio-geochemical	Habitat Provision	Biodiversity	Total SEV Score
SEV 1	NGA_TRIB8_3	0.60	0.37	0.24	0.26	**0.393**
SEV 2	PAH_MAIN_2	0.82	0.38	0.26	0.31*	**0.483**
SEV 3	NGA_TRIB3_3	0.79	0.32	0.42	0.34*	**0.482**
SEV 4	NGA_MAIN_32	0.73	0.92	0.65	0.42	**0.719**
SEV 5	TRIB27_10	0.63	0.32	0.39	0.05	**0.360**

** Vfish function was excluded from calculations due to a lack of NZFFD records or incidental fish observations for these sites.*

5.2 Biodiversity

Fish IBI

Electric fishing was conducted at three sites (SEV 1, 4 and 5), with this data used to calculate the Fish IBI score for these sites, which contributes towards the Biodiversity function score.

No Fish IBI scores were calculated for SEV 2 and 3, where electric fishing wasn't undertaken, as there were no nearby records from the NZ Freshwater Fish Database that could provide a useful indication of the fish species present at these sites. Instead, the Biodiversity function score was calculated without including the IBI scores, so as not to skew the results.

The IBI scores for the three sites at which electric fishing was undertaken were ranked as 'poor' for SEV 1 and 4, with scores of 18 and 26 respectively, while SEV 5 scored 0, as no native fish were caught.

The three sites varied in their distance from the coast and in elevation, from 2.5 km inland and an altitude of 5 m for SEV 1, to 15 km inland and 160 m altitude for SEV 5.

The number of species caught was low, which was reflected in the IBI scores. Only two native species were captured at SEV 1 (inanga and shortfin eel) and SEV 4 (shortfin and longfin eel), while all three sites had exotic mosquitofish present. Thousands of mosquitofish were caught at SEV 5, which was reflective of the high amount of macrophytes and deep sediment present in the channel, as degraded stream conditions are favoured by this species.

While the good riparian cover and hard-bottomed substrate present at SEV 4 would initially appear to provide ideal conditions for native fish, there was a lack of undercut banks or in-stream debris within the reach surveyed. This meant that the range of fish habitat was somewhat limited, and was likely to have resulted in the low number of species detected.

Macroinvertebrate Community Index

Macroinvertebrate samples were taken at all five of the SEV sites. All except for SEV 4 used the soft-bottomed sampling protocols.

A summary of the Macroinvertebrate Community Index (MCI) scores, as well as the number of total taxa and the number of EPT taxa (Ephemeroptera, Plecoptera, Trichoptera) for each site are listed in Table 24.

The MCI scores for all sites apart from SEV 4 were indicative of poor water quality, with the MCI score of 80 for SEV 4 only just qualifying it for the 'fair' category. The overall number of macroinvertebrate taxa found were also limited, ranging from 13 taxa at SEV 4 to only five at SEV 2.

It is notable that only one site (SEV 4) had any EPT taxa, and of the three taxa recorded, one was the axehead caddis *Oxyethira*. *Oxyethira* is an exception to the general rule that EPT taxa tend to be more sensitive and therefore indicative of higher water quality, as it is also common in nutrient enriched streams. This means that the effective EPT score for this site is likely lower than indicated.

The overall results of the macroinvertebrate sampling indicated that all of the sites had depauperate macroinvertebrate communities that were consistent with organic pollution from land use within the surrounding catchment.

Table 24: Summary of biodiversity index values across sites.

Site Code	MCI	No. Taxa	EPT Taxa	Fish IBI Scores
SEV 1	71.75	8	0	18
SEV 2	77.60	5	0	n/a
SEV 3	68.50	8	0	n/a
SEV 4*	80.00	13	3	26
SEV 5	46.00	7	0	0

**Sampled using the hard bottomed protocol, all other sites are soft bottomed sites*

Table 25: Attributes and suggested integrity classes for the Index of Biotic Integrity: Fish (2016).

Total IBI score	Integrity class	Description
54-100	Very Good	Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 80th percentile of Auckland sites
50-53	Good	Site is above the 60th percentile of all Auckland sites species richness is slightly less than best for the region
38-49	Fair	Site is above the 40th percentile of Auckland sites but species richness and habitat or migratory access reduced some signs of stress
26-37	Poor	Site is less than average for Auckland region IBI scores, less than the 40th percentile, thus species richness and or habitat are severely impaired
1-25	Very poor	Site is below the 20th percentile meaning site is impaired or migratory access almost non existent
0	No native fish	Site is grossly impacted or fish access non-existent.

Table 26: Interpretation of Macroinvertebrate Community Index Scores.

MCI Quality Thresholds (Stark et al. 2004, 2007)	
Quality	**MCI score**
Excellent	>119
Good	100-119
Fair	80-99
Poor	<80

5.3 Sediment Chemistry

Composite sediment samples were taken within the stream channel at sites SEV 1, 4 and 5 and analysed for total copper, lead and zinc, as well as polycyclic aromatic hydrocarbons (PAHs).

ISQG – low trigger values are the single-contaminant thresholds where adverse biological effects could occur as an early warning for management intervention. ISQG – high trigger values are indicative of contaminant concentrations where significant biological effects are expected (Table 27).

While SEV 5 recorded the highest levels of heavy metals out of the three sites, none of the sites exceeded the ISQG low trigger values for copper, lead or zinc.

Although SEV 4 had levels of total PAH that were an order of magnitude greater than the next highest reading at SEV 5, all levels were well below ISQG trigger values across all three sites. The reason for SEV 4 to have the highest levels are not immediately apparent, and are possibly due to upstream influences from elsewhere in the catchment.

Table 27: Summary of sediment contaminants (mg/kg/dry wt).

	Zn	Cu	Pb	Total PAH
	(>200 (Low) >410 (high))	*(>65 (Low) >270 (high))*	*(>50 (Low) >220 (high))*	*(>4000 (Low) >45,000 (high))*
SEV 1	41	12.7	10.9	0.090
SEV 4	47	19.2	22	2.774
SEV 5	115	33	25	0.247

5.4 Public Health

Water samples were taken at sites SEV 1, 4 and 5 and analysed for *E. coli*. All sites fell within the 'A' band defined in the 2014 National Policy Statement for Freshwater Management (updated August 2017) National Bottom Line for *E. coli*.

This corresponds to a low risk of infection from contact with water during activities with occasional immersion or ingestion of water e.g. wading and boating. At two sites (SEV1 and SEV4), *E. coli* exceeded 260 cfu per 100 ml. Under the NPS-FW, sampling frequency should be increased to daily monitoring when a single sample exceeds 260 cfu per 100 ml. Although these SEV sites are not primary contact sites, exceeding this limit suggests that a precautionary approach should be taken with regard to water quality at these sites.

Note that the National Policy Statement for Freshwater Management attributes are intended to be assessed based on the annual median, or 95th percentile of samples, not single one-off samples as were taken here.

Table 28: National Policy Statement attribute state - *E. coli*

cfu/100mL	A ≤540	B ≤1000	C ≤1200	D >1200	E >1200
SEV 1	300	-	-	-	-
SEV 4	500	-	-	-	-
SEV 5	40	-	-	-	-

5.5 Summary

All of the five SEV sites surveyed showed compromised ecological integrity. While the SEV scores for all sites indicated 'moderate' ecological values, the macroinvertebrate scores showed that they generally had poor water quality.

SEV 4 had a more depauperate macroinvertebrate community than would be expected given the good riparian vegetation and stable in-stream habitat present. This indicates that factors from upstream in the catchment are likely to be influencing the makeup of the macroinvertebrate community present at the site. Notwithstanding that this site had the highest SEV and MCI scores out of the five sites surveyed, it was still below average in terms of its ecological condition.

The other four sites (SEV 1, 2, 3 and 5) all showed evidence that their ecological values were being compromised by surrounding land-use activities (agriculture for sites SEV 1-3 and market gardening for SEV 5). Limiting factors for these sites included a general lack of canopy cover and poor quality riparian vegetation, high levels of loose sediment within the stream channel, and excessive macrophyte growth.

Based on the results from these five sites, key opportunities to improve SEV scores in the Ngakoroa catchment include fencing off streams in grazed paddocks, riparian planting with native species to improve bank stability and increase shading, and control of sediment run-off from sources such as market gardens.

6.0 Enhancement Opportunities

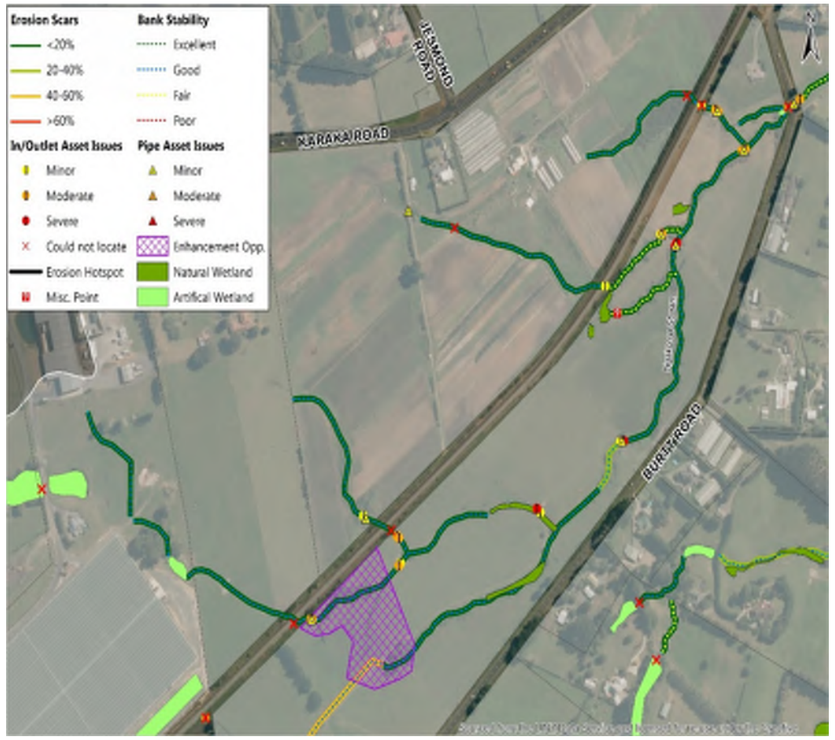
A total of 17 enhancement opportunities were identified within the Ngakoroa catchment. Nine enhancement opportunities are situated within the future urban zone (FUZ), whilst the other eight are in the rural sections of the catchment. Enhancement opportunities outside the FUZ provide an opportunity for holistic enhancement of the Ngakoroa catchment, as these upper reaches have direct impacts on the downstream reaches in the FUZ. Each enhancement opportunity is assigned a high-level prioritisation based on the potential benefits to public and local amenity values, ecological values such as biodiversity and habitat improvements, and conveyance based on the general project works identified below.

Table 29: Summary of prioritisation of enhancement opportunities.

Enhancement Opportunity	Management Zone	Description	Amenity	Ecology	Conveyance	Overall Score	Prioritisation Score
EO 1	**MZ2**	Restore historic wetlands at Burtt Road	M	H	H	11	1
EO 2	**MZ2**	Restore historic hydrology at Runciman Road	M	M	M	9	3
EO 3	**MZ1; MZ2**	Inanga spawning habitat at Ngakoroa stream mouth	M	H	M	10	2
EO 4	**MZ2**	Online ponds at Jesmond Road	M	M	M	9	3
EO 5	**MZ2**	Online ponds at Runciman Road	L	M	M	8	4
EO 6	**MZ2**	Daylighting at Great South Road	M	M	M	9	3
EO 7	**MZ2; MZ6**	Wetland floodplain connectivity at Runciman Road	H	M	H	11	1
EO 8	**MZ2**	Channel naturalisation at Burtt Road	L	L	L	6	5
EO 9	**MZ2**	Channel naturalisation at Great South Road	L	M	M	8	4
EO 10	**MZ6; MZ8**	Ecological enhancement at Coulston Road	M	M	L	8	4
EO 11	**MZ6; MZ7**	Green corridor connectivity at Raventhorpe Scenic Reserve	H	H	M	11	1
EO 12	**MZ8**	Weed control and planting at Helland Drive	M	M	L	8	4
EO 13	**MZ5**	Connecting and enhancing habitat at Great South Road	L	M	M	8	4
EO 14	**MZ6; MZ7**	Connecting forest fragments at Ingram Road	M	H	L	9	3
EO 15	**MZ4**	Erosion remediation and fish passage at SH1	L	M	H	9	3
EO 16	**MZ6**	Fish passage remediation at Patrick Lane	L	H	L	8	4
EO 17	**MZ6**	Enhancing kahikatea forest at Norfolk King Drive	M	H	L	9	3

EO1 – Historic Wetland Restoration

Aerial image from 1942



Location - 647 Burtt Road Drury

Tributary ID NGA_TRIB_3	**Ownership** Private
Asset ID n/a	**Area** 13,765 m^2

Description

Opportunity to restore wetland hydrology and channel morphology. Consideration of potential for constructed wetland for serve stormwater treatment/flood attenuation purposes and or enhance ecological values and diversity.

Upstream inputs from artificial/modified channels and irrigation ponds. Several redundant culverts in very poor condition with moderate to severe erosion for removal. Severe pugging through streams and wetlands.

Considerations

- Stormwater wetland design guidelines
- Catchment size
- Catchment imperviousness
- Surrounding typography
- Maintenance of fish passage
- Contaminated land
- Potential to maximise stream length habitat values, hydrologic variety

Significant Linkages

EO8 - downstream

Additional Information

Historic wetlands near headwaters adjacent to rail line.

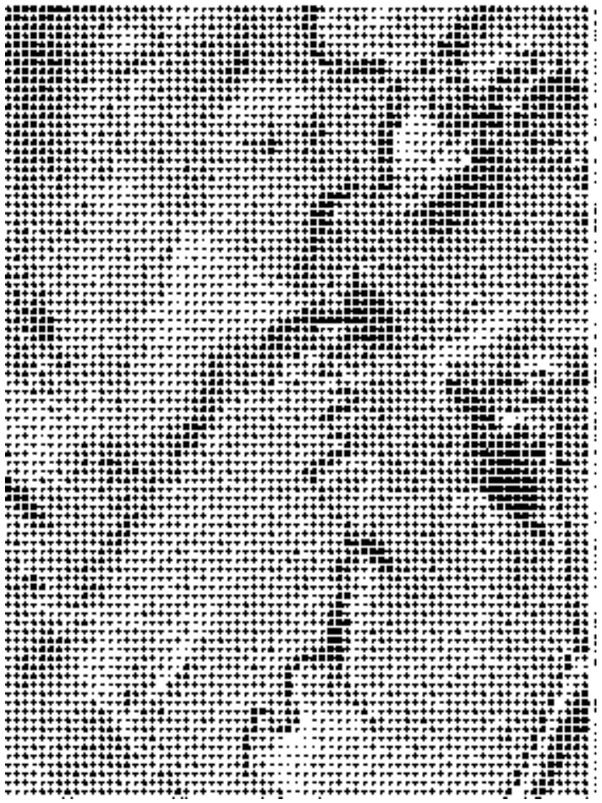
Enhancement Types	Stakeholders
Naturalisation	AC Healthy Waters
Wetland Restoration	AC ESU
Daylighting (culverts)	Kiwirail/NZTA
Conveyance Improvements	Landowners

Severe pugging

Modified channels

Poor condition crossing with erosion issues

EO2 – Restore historic hydrology



Aerial image from 1942

Location – 801 Runciman Road

Tributary ID NGA_TRIB8	**Ownership** Private
Asset ID NGAP_004	**Area** 12,930 m^2

Description

Straightened channel with historic high sinuosity and wetland on true right. Opportunity to restore hydrology and channel morphology and floodplain engagement.

Culvert under private shared driveway displaced and forming partial barrier to fish passage. No significant barriers recorded downstream. Sub-catchment approx. 7 km^2 with >10 km potential upstream habitat.

Considerations

- Maintaining required conveyance capacity
- Existing stream invert and stream gradient
- Potential to maximise stream length, habitat values, hydrologic variety
- Cut/fill volumes
- Surrounding topography
- Provision of appropriate grade controls and maintenance of water depth

Significant Linkages

EO7 – upstream of site

Additional Information

Potential esplanade reserve

Enhancement Types	**Stakeholders**
Naturalisation	AC Healthy Waters
Wetland Restoration	AC ESU
Fish Barrier	Landowners
Conveyance Improvements	Iwi

Confluence with slight erosion and short section of bank lining

Drainage channel through historic wetland on TRB

Culvert outlet showing displaced section and debris jam at inlet

EO3 – Inanga Spawning

Location - 15, 25, 31 Burberry Rd
Ngakoroa Stream Mouth

Tributary ID NGA_MAIN_1	**Ownership** Private
Asset ID n/a	**Area** 16,830 m^2

Description

Remnants of wetland species including watercress, alligator weed, bachelors button grading to raupo. Stock pugging and grazing damage

Potential inanga spawning and coastal wetland enhancement predominantly on TLB. Management interventions could include weed control and stock exclusion before and during spawning season. Further consideration should be given to the suitability of the site for spawning and potential improvements to wetland contours and vegetation if salinity levels are appropriate.

Considerations

- Position of salt wedge and freshwater inputs
- Spring high tide levels
- Sea level rise scenarios
- Bank height/slope
- Appropriate vegetation for spawning

Significant Linkages

Additional Information

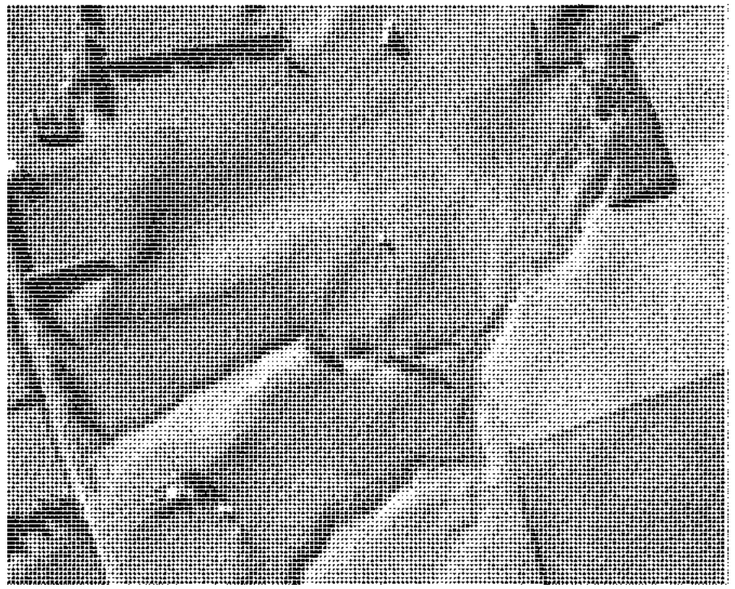
Potential esplanade on TLB.
Public open space on TRB (Drury Football Club)
Historical imagery shows wetland in similar position to current

Enhancement Types	Stakeholders
Naturalisation	AC ESU
Wetland Restoration	AC Parks
Fish Barrier	Iwi
Conveyance Improvements	Residents

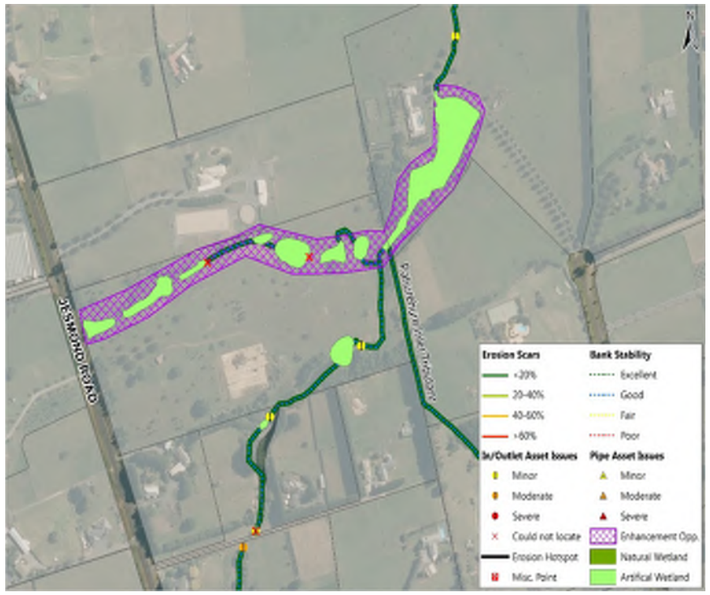
Facing downstream, tidal Ngakoroa stream mouth

Adjacent wetland

EO4 – Online Ponds –Jesmond Road



Aerial image from 1942



Location - 221 Jesmond Road

Tributary ID PAH_MAIN_4	**Ownership** Private
Asset ID n/a	**Area** 20,170 m^2

Description

Series of seven small and one large online ponds.

Opportunity to remove ponds to address associated impacts on water quality and freshwater ecology.

Potential to consider creation of a wetland (offline) for the purposes of stormwater treatment/flood attenuation and or enhancement of habitat diversity.

Considerations

- Catchment size and position in catchment
- Existing depth of pond
- Existing stream invert
- Surrounding topography
- Cut/fill volumes
- Stream gradient
- Sediment and erosion control methodology
- Appropriate works methodology to avoid acute impacts on downstream water quality and potential proliferation of exotic pests
- Erosion and scour protection
- Maintenance of fish passage

Significant Linkages

Potential esplanade reserve downstream

Additional Information

Some historical evidence of possible oxbow wetland within footprint of largest pond.

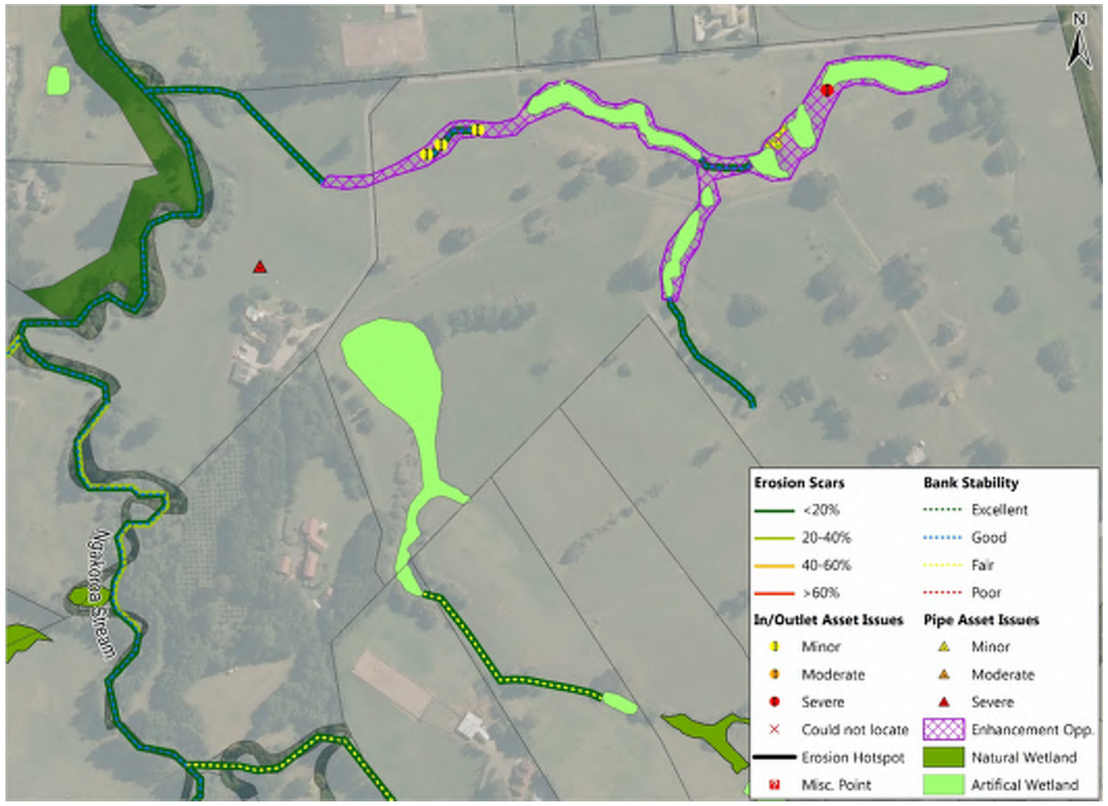
Enhancement Types	Stakeholders
Naturalisation	AC Healthy Waters
Conveyance Improvements	AC Parks
Daylighting (culverts)	AC ESU
Fish Barrier	Auckland Transport

Typical smaller pond upstream

Largest pond

Clusters of pipes between ponds form barrier to fish passage

EO5 – Online Ponds –Runciman Road



Location – 1136a Great South Rd

Tributary ID NGA_TRIB_5	**Ownership** Private
Asset ID n/a	**Area** 9,960 m^2

Description

Series of online ponds with numerous culverts.

Opportunity to remove ponds to address associated impacts on water quality and freshwater ecology.

Collectively approximately 800 m of potential habitat enhancement for fish communities, however no further upstream habitat.

Considerations

- Catchment size and position in catchment
- Existing depth of pond
- Existing stream invert
- Surrounding topography
- Cut/fil volumes
- Stream gradient
- Sediment and erosion control methodology
- Appropriate works methodology to avoid acute impacts on downstream water quality and potential proliferation of exotic pests
- Erosion and scour protection
- Maintenance of fish passage

Significant Linkages

EO6 - same property

Additional Information

Ponds follow general alignment of former stream channel.

Enhancement Types	**Stakeholders**
Naturalisation	AC Healthy Waters
Conveyance Improvements	AC ESU
Daylighting (culverts)	Residents
Fish Barrier	

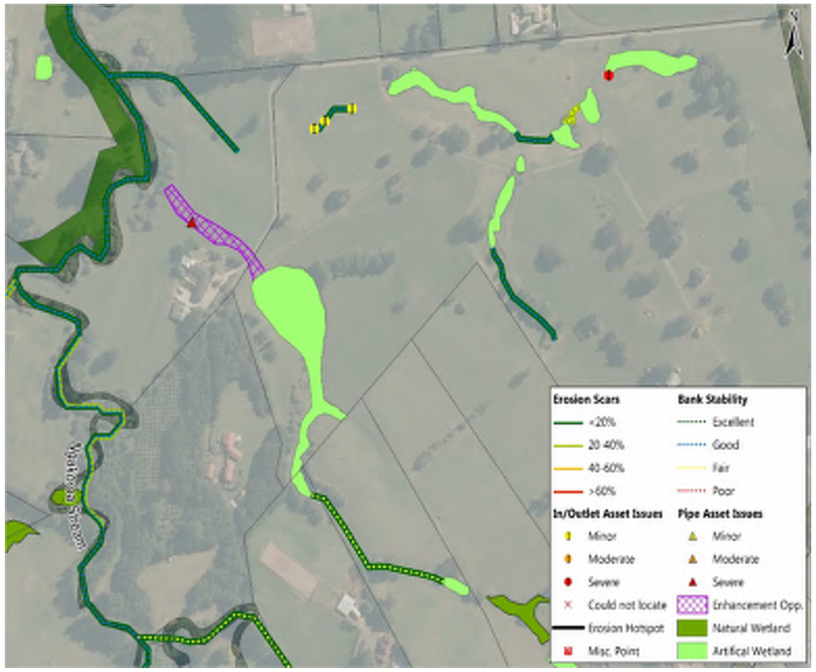
Pond partially shaded by willow

Pond dominated by water lily

Typical dam and pipe between ponds

EO6 – Daylighting

Aerial image from 1942



Location - 1136a Great South Rd

Tributary ID NGA_TRIB_6 **Ownership** Private

Asset ID n/a **Area** 1,380 m^2

Description

Daylighting opportunity approximately 100 m downstream of pond.
Known flooding issues with driveway at pond dam and pipe has collapsed in the middle of the paddock downstream.
Collectively approximately 800 m of potential habitat enhancement for fish communities however no further upstream habitat.

Considerations

- Catchment size and position in catchment
- Existing depth of pond
- Existing stream invert
- Surrounding topography
- Cut/fil volumes
- Stream gradient
- Sediment and erosion control methodology
- Appropriate works methodology to avoid acute impacts on downstream water quality and potential proliferation of exotic pests
- Erosion and scour protection
- Maintenance of fish passage

Significant Linkages

EO5 – same property

Additional Information

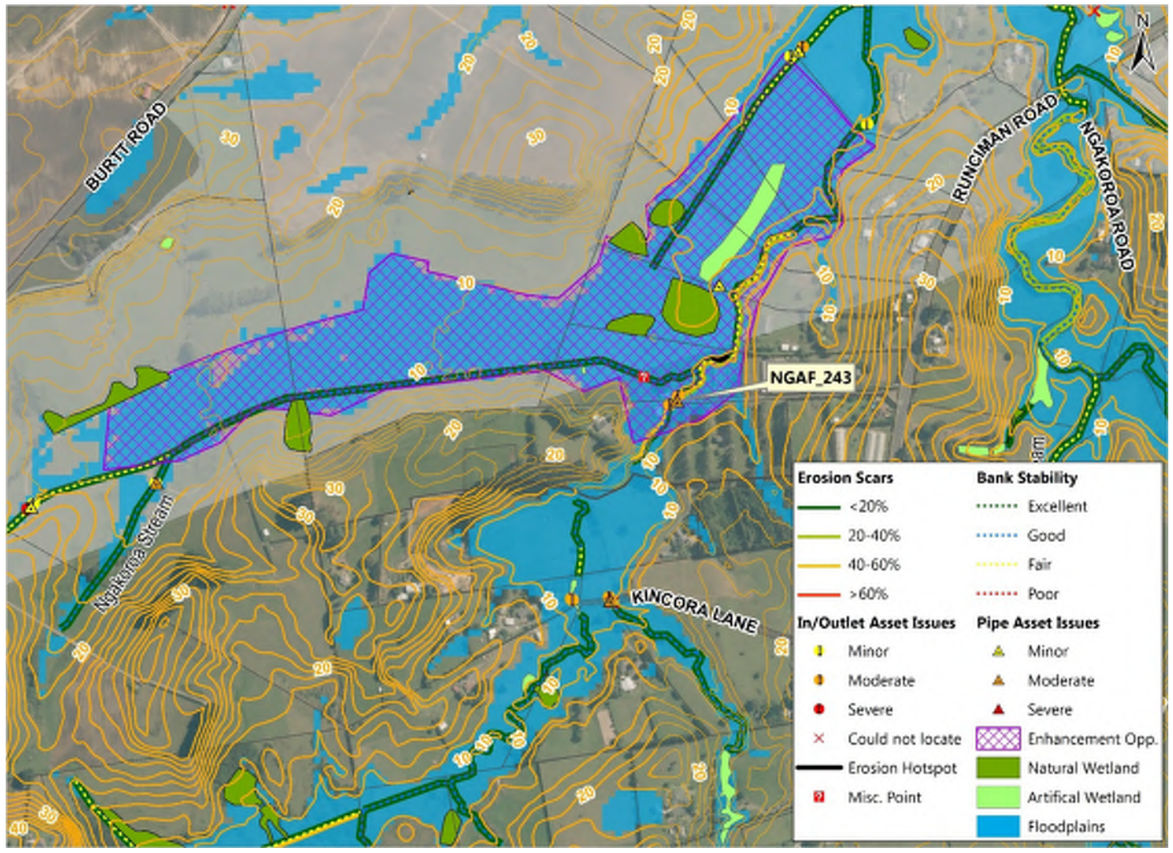
Enhancement Types	Stakeholders
Daylighting	AC Healthy Waters
Conveyance Improvements	AC ESU
Erosion Protection	Residents
Fish Barrier	

Piped here, collapsed underground

Outlet of pipe

Online pond

EO7 –Extensive Floodplain Wetlands



Location - North from 763A Runciman Road

Tributary ID NGA_TRIB8 and NGA_TRIB8a **Ownership** Private

Asset ID n/a **Area** 216,573 m^2

Description

Extensive floodplain with numerous wetlands throughout. Modified channels with variable flow direction. Residents have reported issues at upstream culvert under shared driveway resulting in flooding of non-habitable floors and limiting access to property.

Anecdotal evidence that stream can overflow into floodplain when high flows coincide with high tide and backing up behind culvert affecting other upstream properties.

Opportunity to create public open space for passive recreational use combined with stormwater management. This could include pockets of detention basins, integrated with a naturalised stream corridor to increase sinuosity with consideration of conveyance capacity.

Considerations

- Catchment size and position in catchment
- Existing stream invert and gradient
- Surrounding topography
- Cut/fil volumes
- Potential to maximise stream length, habitat values, hydrologic variety
- Flood modelling
- Appropriate works methodology to avoid acute impacts on downstream water quality and potential proliferation of exotic pests
- Erosion and scour protection
- Maintenance of fish passage
- Provision of appropriate grade control

Significant Linkages

EO2 – downstream channel naturalisation

Additional Information

Erosion hotspot downstream of culvert on TLB approx. 7 m from power pylon

Enhancement Types	**Stakeholders**
Conveyance Improvements	AC Healthy Waters
Naturalising	AC ESU
Erosion Protection	Landowners
Weed Control and Planting	Iwi

View from southern farm drain towards north across floodplain

Outlet of culvert with noted flooding issues. Partially submerged.

Facing downstream (east) on southern tributary

EO8 – Channel Naturalisation

Location - 636/650 Burtt Road

Tributary ID NGA_TRIB_3 **Ownership** Private

Asset ID n/a **Area** 1,865 m^2

Description

Reach immediately upstream has been fenced and planted. Reach is lined and straightened and dominated by aquatic weeds including parrots feather and bordered by mature pine shelter belt.

Opportunity to restore hydrology and channel morphology and floodplain engagement and potentially remove culvert.

Considerations

- Maintaining required conveyance capacity
- Potential to maximise stream length, habitat values, hydrologic variety
- Existing stream invert and stream gradient
- Cut/fill volumes
- Surrounding topography
- Provision of appropriate grade controls and maintenance of water depth

Significant Linkages

EO1 - Upstream

Additional Information

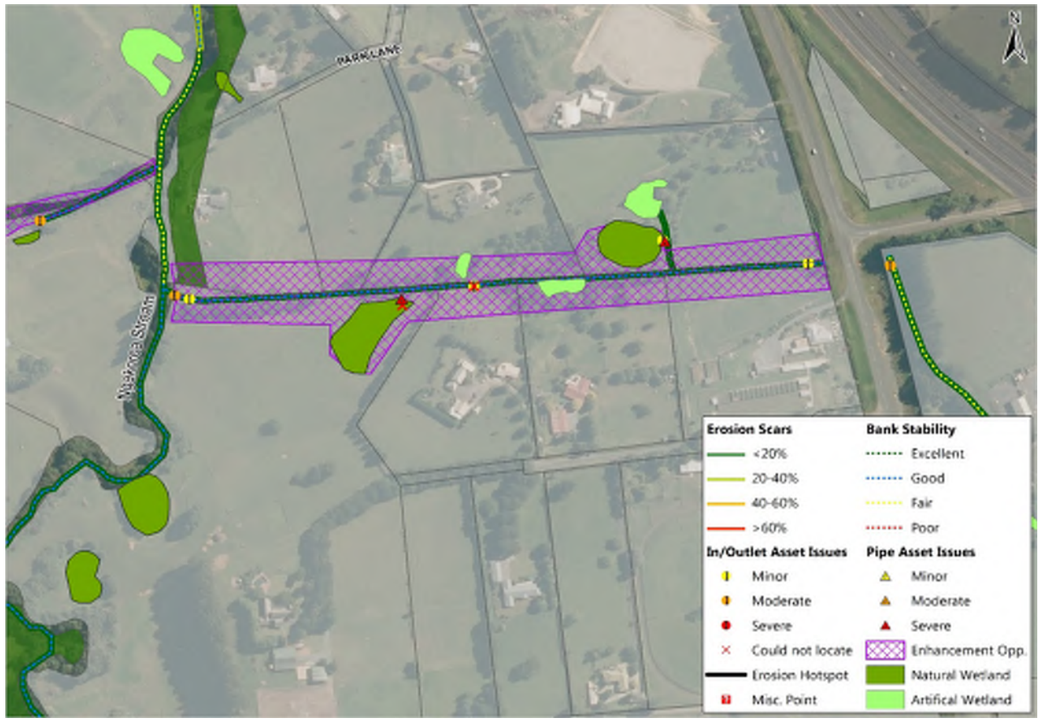
Enhancement Types	Stakeholders
Naturalising	AC Healthy Waters
Erosion Protection	AC ESU
Aquatic Weed Control	Landowners
Weed Control and Planting	Auckland Transport

5 m length timber lining with cross beam reinforcing at culvert outlet

Facing upstream

Two concrete and cast-iron pipes at culvert outlet

EO9 – Channel Naturalisation



Location - 685-813 Great South Road

Tributary ID NGA_TRIB4 **Ownership** Private

Asset ID n/a **Area** 1,865 m^2

Description

Opportunity to naturalise straightened channel and adjacent wetlands to reintroduce meanders and habitat heterogeneity and floodplain engagement.

Considerations

- Maintaining required conveyance capacity
- Potential to maximise stream length, habitat values, hydrologic variety
- Existing stream invert and stream gradient
- Cut/fill volumes
- Surrounding topography
- Provision of appropriate grade controls and maintenance of water depth

Significant Linkages

Additional Information

Historic imagery shows straightened channel in this location.
Wetland on TLB has been fenced and planted with Manuka and flax.

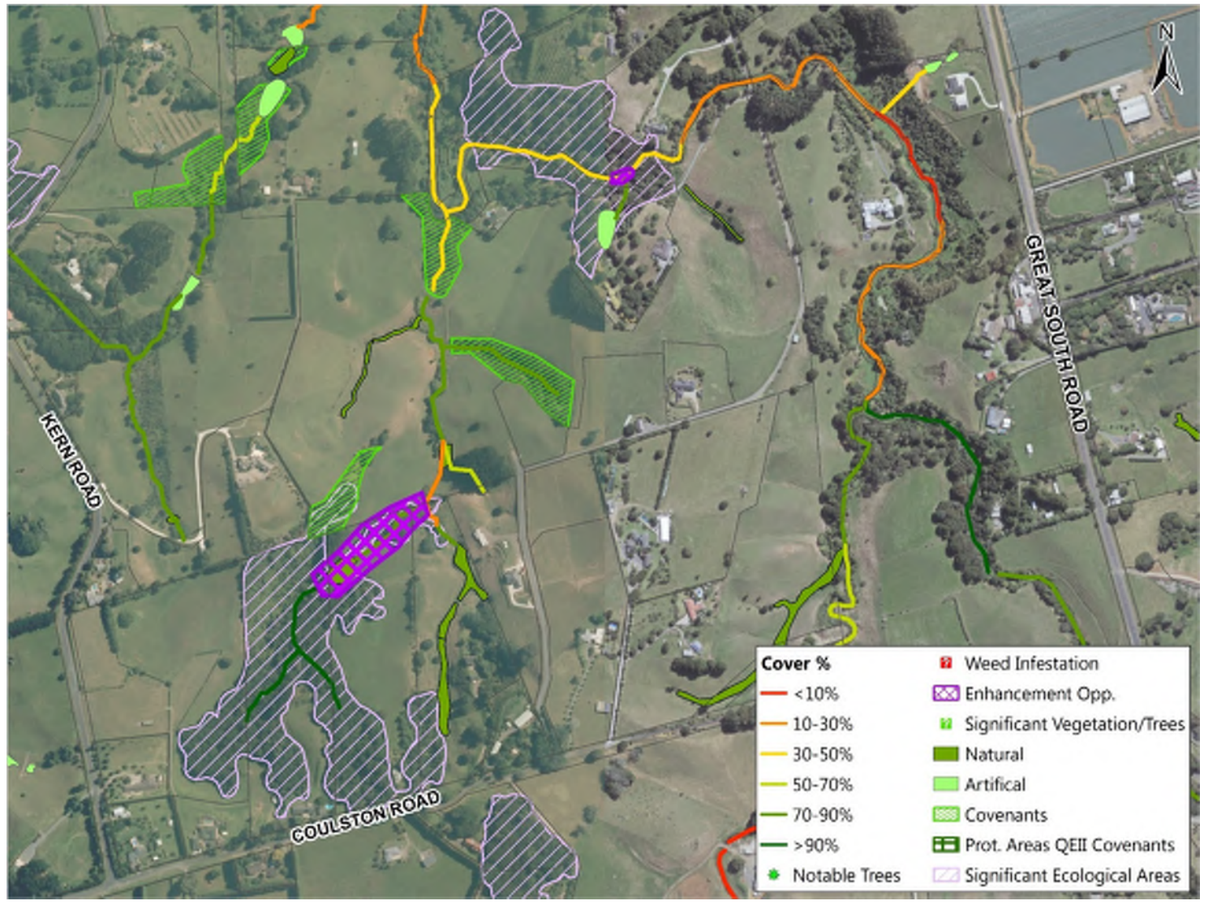
Enhancement Types	Stakeholders
Naturalising	AC Healthy Waters
Conveyance Improvements	NZTA
Amenity	Residents
Weed Control and Planting	AC ESU

Straightened channel dominated by blackberry

Straightened channel with shelter belt

Moderate erosion at outlet from channel to main stream.

EO10 – Ecological Enhancement



Location – 21-49 Coulston Road, Pukekohe, Auckland (rural)

Tributary ID TRIB16_7; NGA_MAIN_24 **Ownership** Mixed

Asset ID n/a **Area** 7,880 m^2

Description

Opportunity to exclude stock from stream and banks. Re-vegetation through planting of native understorey species would improve the ecological value of the stream, reduce erosion and increase connectivity between native bush fragments.

Waterfall and plunge pool at NGA_MAIN_24 has high potential amenity value.

Considerations

- Erosion and scour protection
- Maximising riparian buffer width to reduce extent of edge habitat and improve sustainability of planting
- Maintaining required conveyance capacity through floodplain appropriate species
- Water quality for recreational use

Significant Linkages

Existing public reserve downstream on TLB at Old Coach Way (NGA_MAIN_24)
High value fish habitat upstream
Significant ecological areas

Additional Information

New culvert crossings with provision for fish passage (baffles etc.) and riparian planting undertaken downstream (associated with recent subdivision)

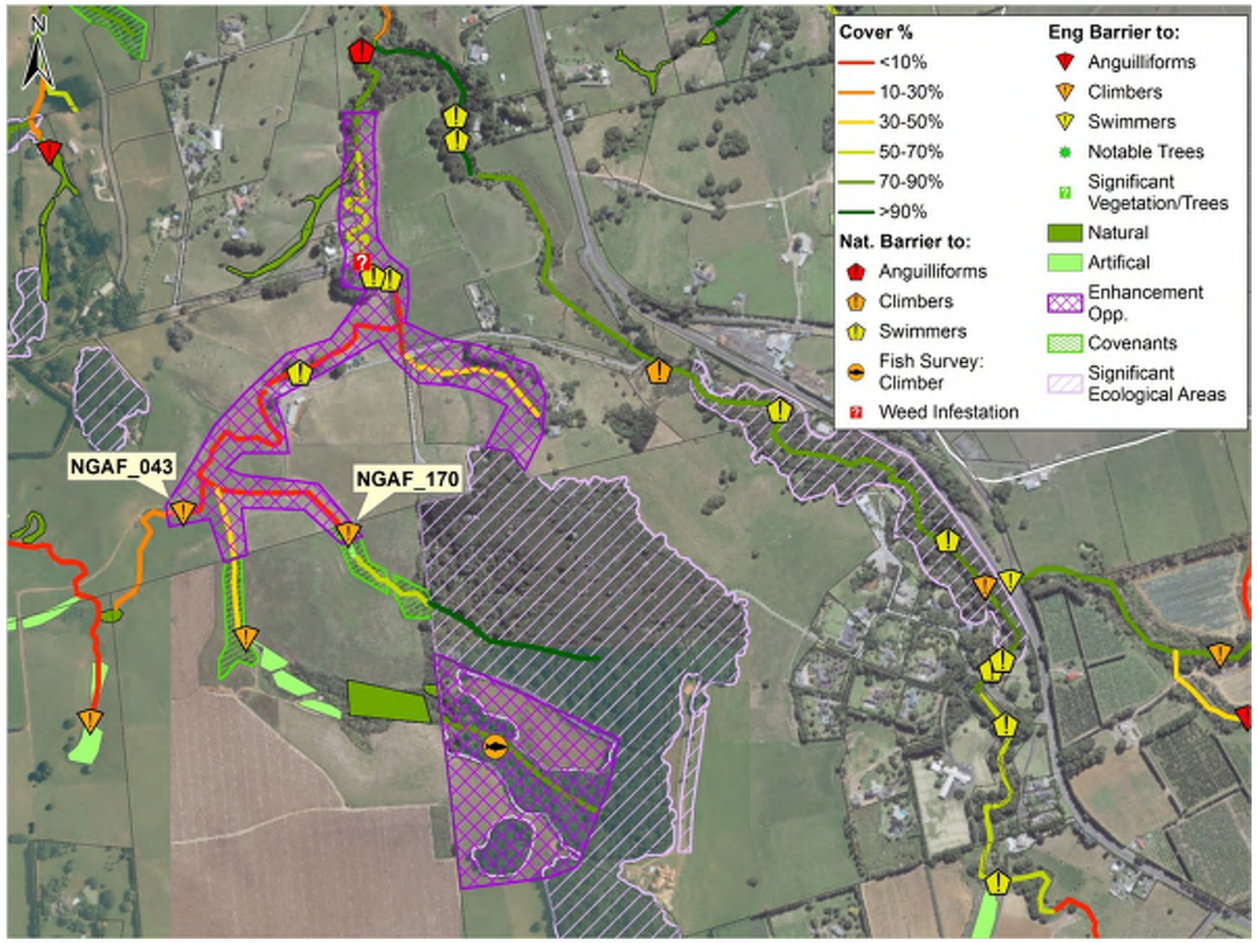
Enhancement Types	**Stakeholders**
Fencing / Stock Exclusion	Residents
Weed Control and Planting	AC – Biodiversity
Amenity	AC - Parks
Safety Improvement	

Poor density of upper bank vegetation with stability provided by existing trees

Mature canopy with damaged understory

Waterfall and plunge pool

EO11 – Enhancing Connectivity and Reducing Forest Fragmentation



Location – Raventhorpe Scenic Reserve

Tributary ID: TRIB17 **Ownership** Mixed
Asset ID NGAF_043; NGAF_170 **Area** 172,035 m^2

Description

Several opportunities for enhancement including:

- Potential public access and amenity values; through connections from the main Ngakoroa Stream to Raventhorpe Scenic Reserve, several large cascades including a scenic waterfalls and plunge pools for potential swimming sites between Coulston and Ambush Roads.
- Removal or update of rural culvert limiting access to upstream potential spawning habitat (NGAF_170) and perched culvert on main tributary (NGAF_043)
- Enhance connectivity and reduce fragmentation of remnant forest (SEA, Taraire forest)
- Enhance damaged understory and control deer within Raventhorpe Scenic Reserve

Considerations

- Potential esplanade reserve on main channel of Trib 17
- Biosecurity – kauri may be present
- Maximising riparian buffer width to reduce extent of edge habitat and improve sustainability of planting
- Water quality

Significant Linkages

Existing public reserves. Existing covenants. SEA's

Additional Information

Downstream natural barriers to fish passage – 7-10 m high waterfalls
Weed infestation – *Arundo donax* downstream

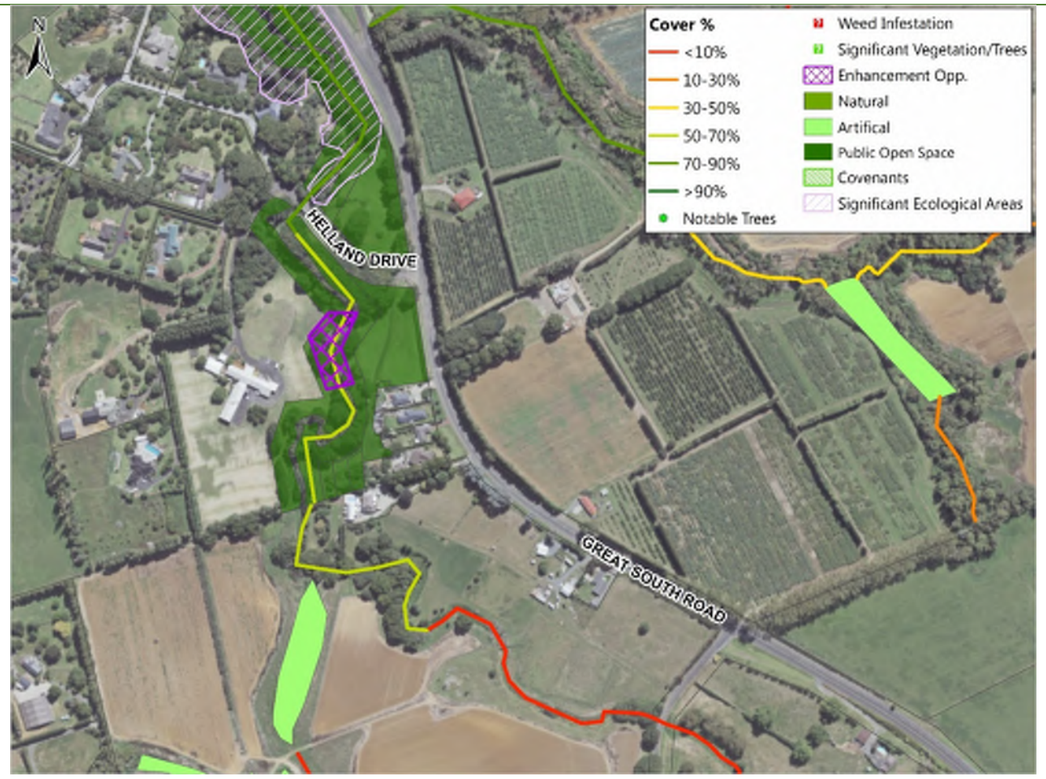
Enhancement Types	**Stakeholders**
Weed Control and Planting	Residents
Amenity	Community Groups
Fish Passage	AC - Biodiversity
Fencing/Stock Exclusion	AC - Parks

Perched undercut culvert limiting access to upstream habitat

Potential banded kokopu spawning habitat upstream at Trib17_58

Waterfall and plunge pool at Trib17_1 off Coulston Rd

EO12 – Weed Control and Planting



Location – Adjacent to 20 Helland Drive, Drury

Tributary ID NGA_MAIN_33 **Ownership** Public

Asset ID n/a **Area** 1,840 m^2

Description

Potential to control glyceria and undertake riparian planting to make a more continuous corridor with downstream habitat. Evidence of sediment run-off from upstream land-use.

Considerations

- Maintaining required conveyance capacity through floodplain appropriate species
- Amenity values and accessibility

Significant Linkages

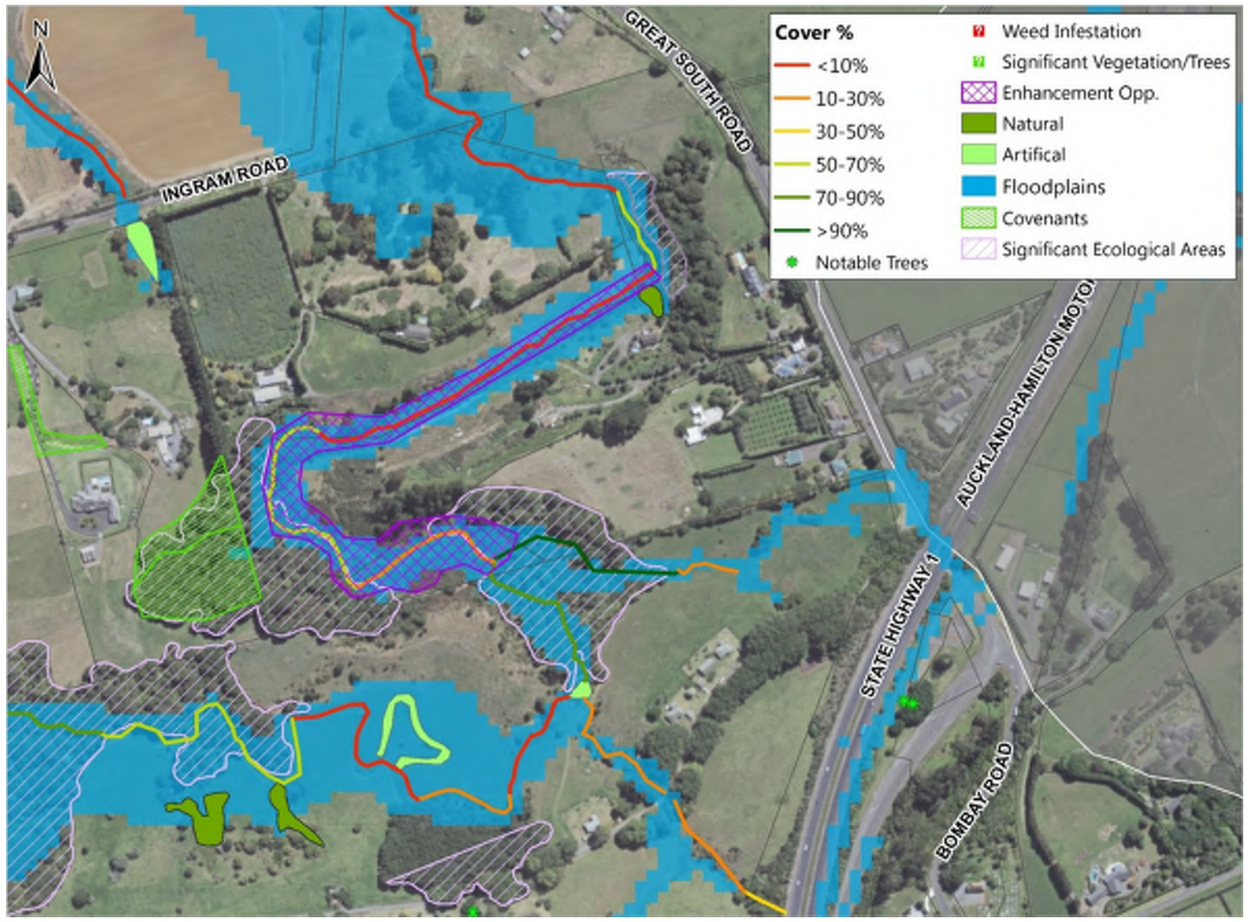
Upstream of an Natural Stream Management Area
SEA
Public Reserves

Additional Information

Reach is part of the Martyn Farm Estate Reserve

Enhancement Types	Stakeholders
Weed control and planting	AC - Parks
Community Engagement	Residents
Amenity	AC - Biodiversity
	Community Groups

EO13 – Connecting and Enhancing Habitat



Location – 1812 Great South Road, Drury

Tributary ID NGA_MAIN_38-40 **Ownership** Private

Asset ID n/a **Area** 19,117 m^2

Description

Opportunity to connect existing areas of regenerating bush and enhance riparian margins around stream. Stream banks consist of large stands of gorse, woolly nightshade and blackberry with glyceria dominated floodplains. Stream has a high-quality boulder substrate but is compromised by sediment inputs from upstream and a lack of shading. Good shade from native forest on true left bank of stream reach. NGA_MAIN_38 appears to have been historically straightened and there are some areas with higher erosion where the channel may be reverting to a meandering form.

Considerations

- Maintaining required conveyance capacity through floodplain appropriate species
- Management of flood plain and short-term sediment transport and increased erosion in response to increased shading
- Maximising riparian buffer width to reduce extent of edge habitat and improve sustainability of planting
- Potential to maximise stream length, habitat values, hydrologic variety
- Potential esplanade reserve opportunities through subdivision

Significant Linkages

SEA
Downstream EO12

Additional Information

Upstream property at 1832 Gt South Rd was not accessible but further enhancement opportunities are likely

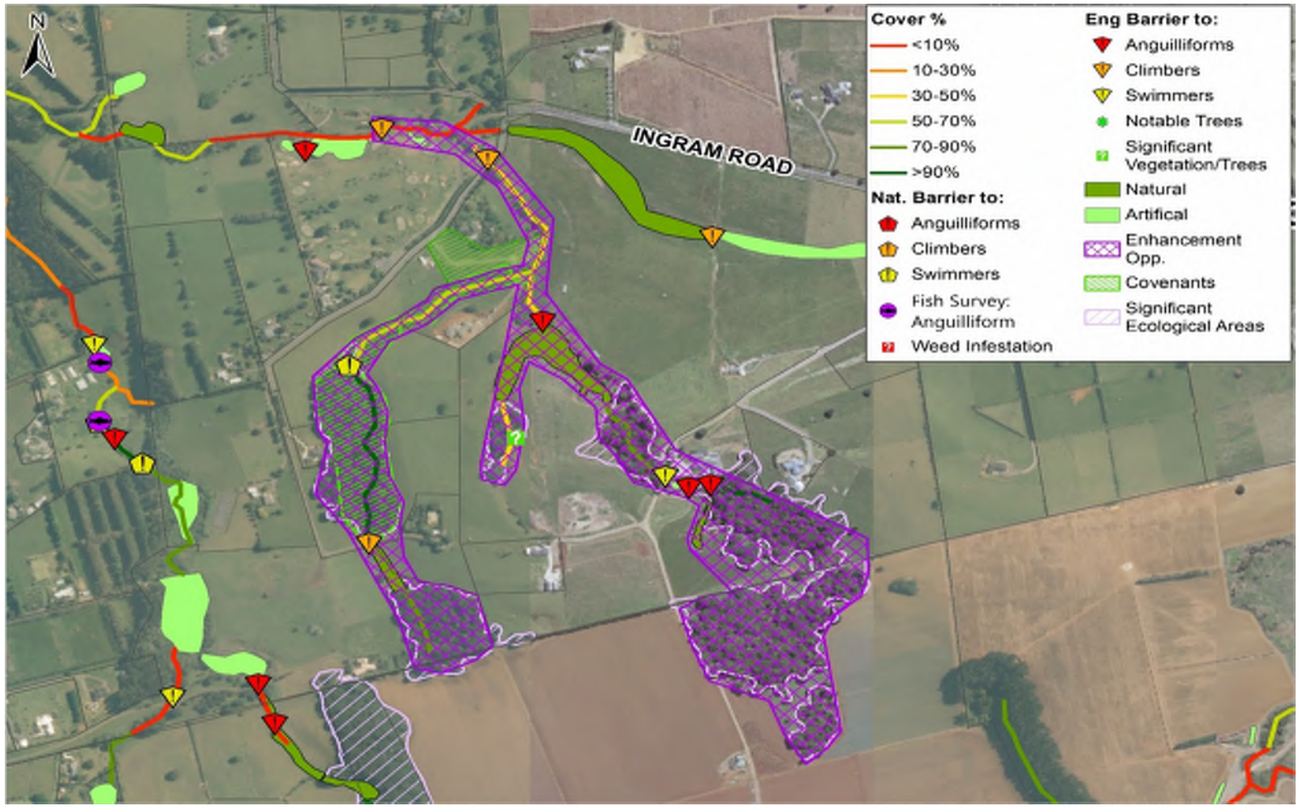
Enhancement Types	Stakeholders
Weed control and planting	Community Groups
Naturalising (Habitat enhancement)	Residents
Aquatic Weed Control	AC - Biodiversity

Boulder substrate provides opportunity for instream fish habitat for bully species.

Opportunity to undertake weed control and revegetate stream banks to increase in-stream shading.

Extensive beds of *Egeria densa* present in stream channel, suggestive of low stream shading and higher nutrient inputs.

EO14 – Connecting Forest Fragments and Fish Habitat



Location – 142 Runciman Road and 205 Ingram Road, Drury

Tributary ID TRIB17_24; TRIB17_25; TRIB17_27; TRIB17_28; TRIB17_29; TRIB17_30; TRIB17_31; TRIB17_32; TRIB17_33; TRIB17_34. **Ownership** Private

Asset ID NGAF_033; NGAF_139; NGAF_024 **Area** 190,250 m^2

Description

Reduce fragmentation and edge extent between remnant puriri forest and taraire forest on stream corridor and enhancement of existing vegetation through weed control.

High quality upstream habitat with a series of barriers to fish passage associated with driveways for recent residential subdivision. Up to 1.5 m high perched and undercut.

Considerations

- Maximising riparian buffer width to reduce extent of edge habitat and improve sustainability of planting

- Maximising riparian buffer width to reduce extent of edge habitat and improve sustainability of planting

Significant Linkages

SEAs and existing covenant
Downstream EO11

Additional Information

Downstream natural barriers to fish passage – 7-10 m high waterfalls
Golf Course at 205 Ingram Rd

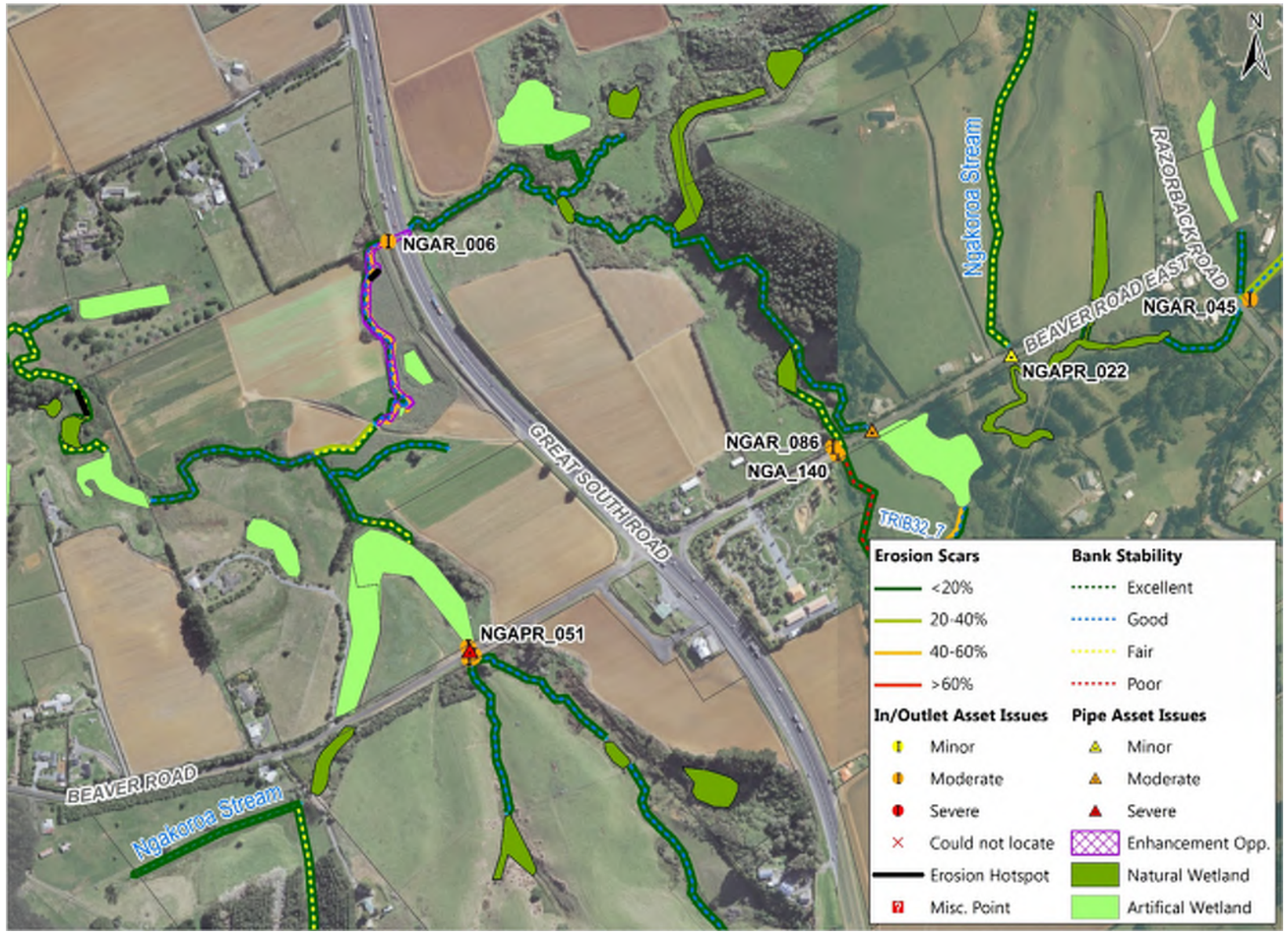
Enhancement Types	Stakeholders
Fish Barrier	Residents
Weed control and planting	AC - Biodiversity
Naturalising (habitat enhancement)	Iwi
Aquatic weed control	

Extensive aquatic weed cover over channel.

Box culvert at golf course at Ingram Rd (NGAF_033)

Cobble and boulder dominant upstream reach (TRIB17_27)

EO15 – Erosion remediation and Fish Passage



Location – 2132 SH Way 1 (near Beaver Road off-ramp)

Tributary ID NGA_MAIN_68 **Ownership** Mixed

Asset ID NGAR_006; NGAPR_051; NGAR_086 **Area** 3,000 m^2

Description

Erosion hotspot downstream of motorway culvert with erosion predominantly on TLB. Further investigation of erosion protection works and conveyance requirements, including potential bank regrading and planting.
Lots of small drainage pipes into reach from surrounding crop land may be exacerbating erosion.
Cluster of other poor condition culverts on Beaver Rd for coordination of maintenance actions. The dual culvert under the motorway is perched and presents a barrier to fish passage.

Considerations

- Catchment size and position in catchment
- Existing stream invert
- Surrounding topography
- Cut/fil volumes
- Stream gradient
- Sediment and erosion control methodology
- Appropriate works methodology to avoid acute impacts on downstream water quality and potential proliferation of exotic pests
- Erosion and scour protection
- Maintenance of fish passage

Significant Linkages

Additional Information

Approximately >2 km potential upstream habitat above fish passage barrier.

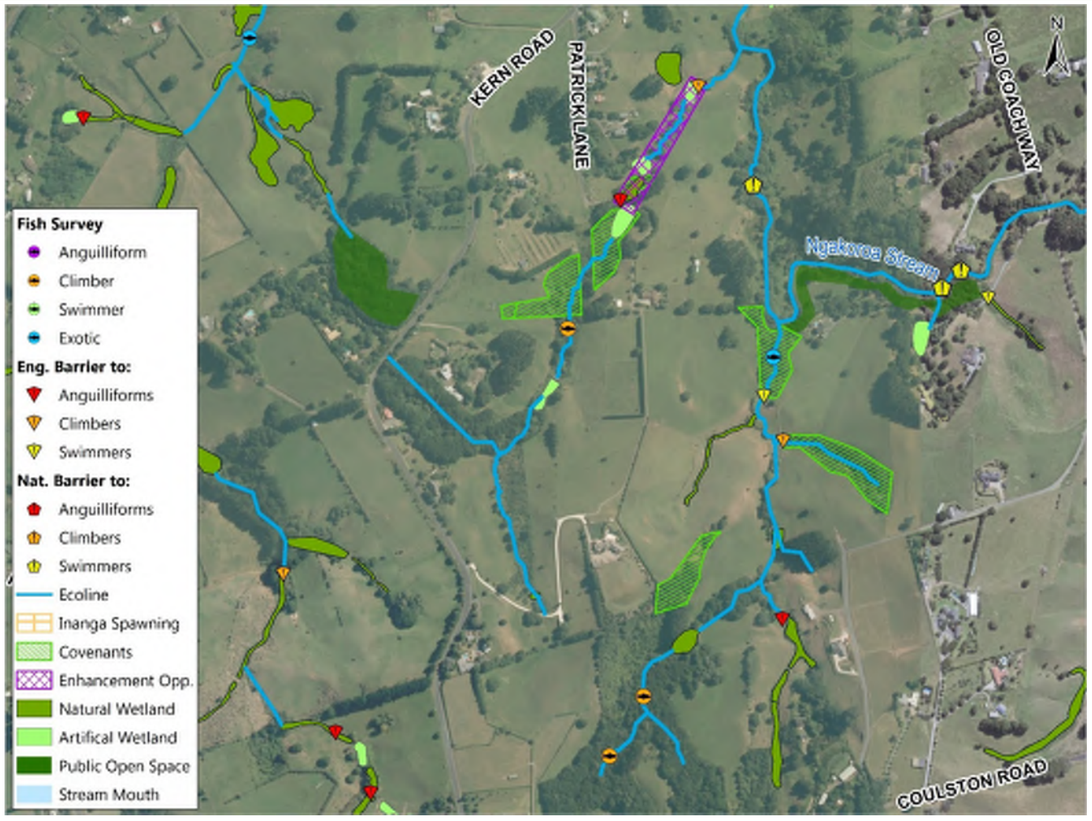
Enhancement Types	Stakeholders
Erosion Protection	NZTA
Conveyance Improvements	AT
Weed control and planting	AC – Healthy Waters
Fish Passage	Residents

Opportunity to undertake streamside weed control and plantings

Culvert outfall under motorway (NGAR_006)

Erosion hotspot 30 m downstream of motorway outlet

EO16 – Fish Passage Remediation



Location – 29 Patrick Lane

Tributary ID TRIB15_16 **Ownership** Private

Asset ID NGAF_130; NGAF_117 **Area** NA

Description

Series of perched culverts limiting access of climbing species to prime wetland and stream habitat upstream. Culvert is perched by 0.8m and, although it appears to be a complete barrier, one adult banded kokopu was observed upstream. Upstream has good fish habitat, with wide shallow stream containing deep sediment running underneath native canopy. Good spawning habitat for banded kokopu in vegetation on floodplain adjacent to channel.

Considerations

- Catchment size and position in catchment
- Stream gradient
- Erosion and scour protection
- Maintenance of fish passage
- Sediment and erosion control methodology
- Appropriate works methodology to avoid acute impacts on downstream water quality and potential proliferation of exotic pests

Significant Linkages

Upstream remnant kahikatea forest

Additional Information

Existing covenant of riparian corridor

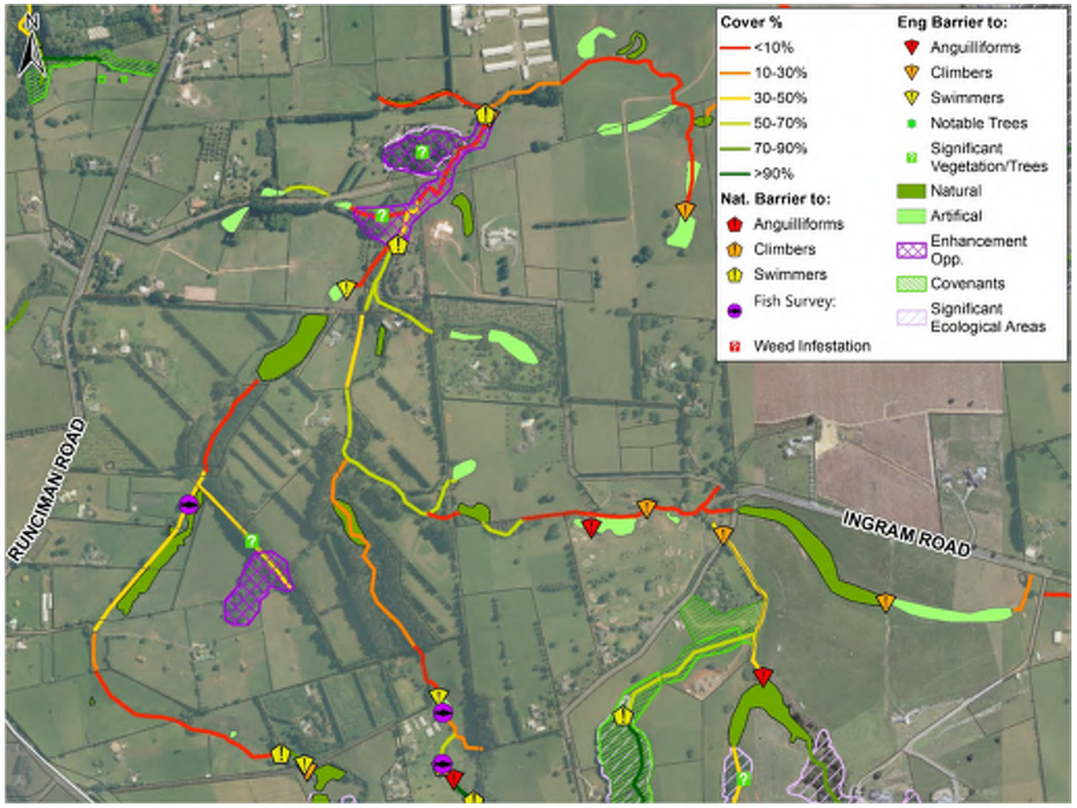
Enhancement Types	Stakeholders
Fish Barrier	Residents
Weed Control and Planting	Community groups
	AC Biodiversity
	Iwi

Perched culvert 0.8m above stream channel, creating a fish passage barrier (NGAF_117)

High value fish habitat in upstream reach

Perched culvert NGAF_130

EO17 – Kahikatea Forest



Location – Norfolk King Drive

Tributary ID TRIB17_15; TRIB17_49 **Ownership** Private

Asset ID n/a **Area** 32,790 m^2

Description

Connectivity of remnant kahikatea dominant forest fragments and enhancement of existing vegetation.

Maintenance and enhancement of wetland hydrology to protect high value remnant habitat.

Considerations

- Catchment size and position in catchment
- Stream gradient
- Surrounding topography
- Maximising riparian buffer width to reduce extent of edge habitat and improve sustainability of planting

Significant Linkages

Upstream remnant Kahikatea forest

Additional Information

Existing covenant of riparian corridor

Enhancement Types	Stakeholders
Naturalising (Habitat Enhancement)	Residents
Fencing and stock exclusion	Community groups
Weed Control and Planting	AC Biodiversity
Community Engagement	Iwi

TRIB17_15

Straightened channel through remnant forest TRIB17_49

Downstream deforested reach with wetland like hydrology TRIB17_49

7.0 Conclusions

The Ngakoroa catchment is predominantly rural, with a large amount of market-gardening land use in the eastern and southern parts of the catchment. This land use is a significant contributor to the high levels of sedimentation recorded throughout the catchment, as a large number of tributaries are showing evidence of excessive loading of fine sediment despite levels of bank erosion generally being low. This indicates that the source of much of the fine sediment is most likely to be market gardening operations, where evidence of soil runoff from cultivated fields into adjacent streams was commonly observed during field assessments.

Addressing the impact of this land use by ensuring that best-practice management is implemented to restrict the amount of soil runoff from areas under cultivation is a key factor in improving the condition of streams in this catchment, as well as potentially reducing the effects of sedimentation on the Pahurehure Inlet and wider Manukau Harbour environments.

Hicks (2006) commented that market gardening contributed large quantities of sediment to streams within the Franklin District but that the majority settled out along the upper reaches of streams, forming riparian wetlands. He came to the conclusion that soil runoff from market gardening was not a significant source of sediment to the Manukau Harbour. Further investigation into the fate of sediment discharged from market gardens would be beneficial for determining the effects on the environment, both on a catchment and wider scale.

Within the FUZ there is evidence of historical modification of a number of tributaries within an area that would have formerly contained natural wetlands. The future development of this area is likely to provide opportunities to re-establish wetland hydrology and provide capacity for stormwater and flood attenuation within this zone.

Fragments of native forest surrounding the upstream extent of small first-order tributaries remain in some areas of the catchment. Opportunities to enhance these areas and increase connectivity with other patches of existing native vegetation within the catchment are encouraged.

The eight Management Zones outlined in this report each include a detailed list of specific issues within the zone and recommendations for addressing these issues. These cut across the themes of watercourse assets, riparian reserves and also future development. The maintenance requirements of assets and erosion points are further detailed in the report and consolidated in Appendix 2. Unnecessary culverts, particularly those on private land, are recommended to be removed and riparian planting protection of at least 10 m in width established where none exists. The avoidance of watercourse and wetland loss are recommended as a guiding principle.

A total of 17 Enhancement Opportunities have been identified that further support the issues within the Management Zones and provide recommendations for restoration and environmental enhancement, both inside and outside of the FUZ.

The extensive development that will occur within the Ngakoroa catchment in the near future will increase pressures on the freshwater environment through the creation of larger amounts of impervious surfaces and the corresponding increase in stormwater runoff. Conversely, additional opportunities will be created through the consenting process to improve ecological functionality in currently degraded areas of the catchment, along with the ability to set aside areas for public amenity value and stormwater attenuation.

Incorporating the proposed Enhancement Opportunities into the framework for future catchment planning will serve to maximise the potential ecological improvements to the catchment and reduce the impact of residential development on the freshwater environment.

8.0 References

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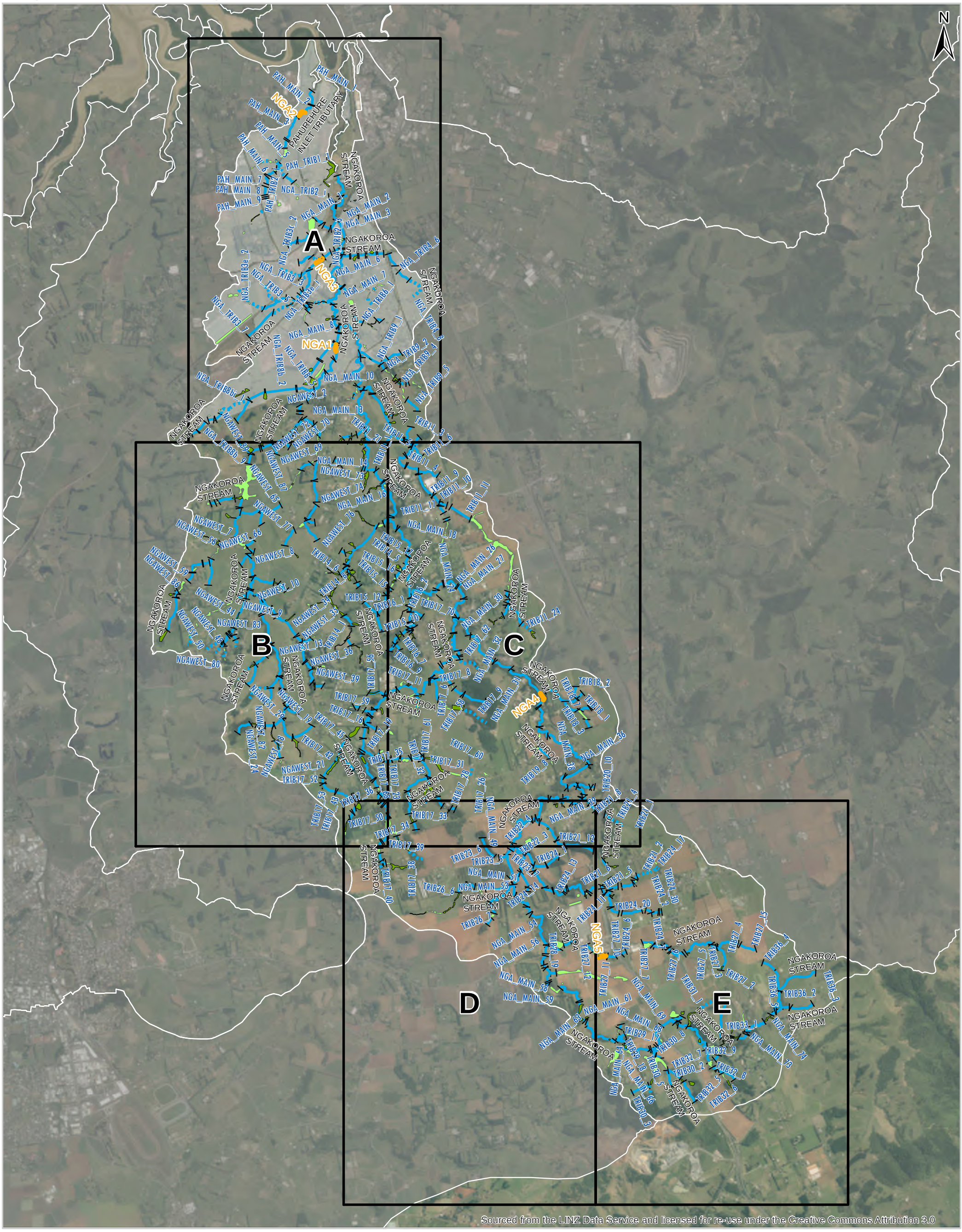
Appendix 1 Maps

Map 1 - Overview Map



Ecoline (WAM)

- Permanent
- Intermittent
- Ephemeral

Wetland

- Natural
- Artifical

- Stormwater Catchments
- Future Urban Zone

- SEV Lines

Client AUCKLAND COUNCIL
Project **NGAKOROA WAR**

0 1 2 km

Project no. P01644
Date 15 Jun 2018

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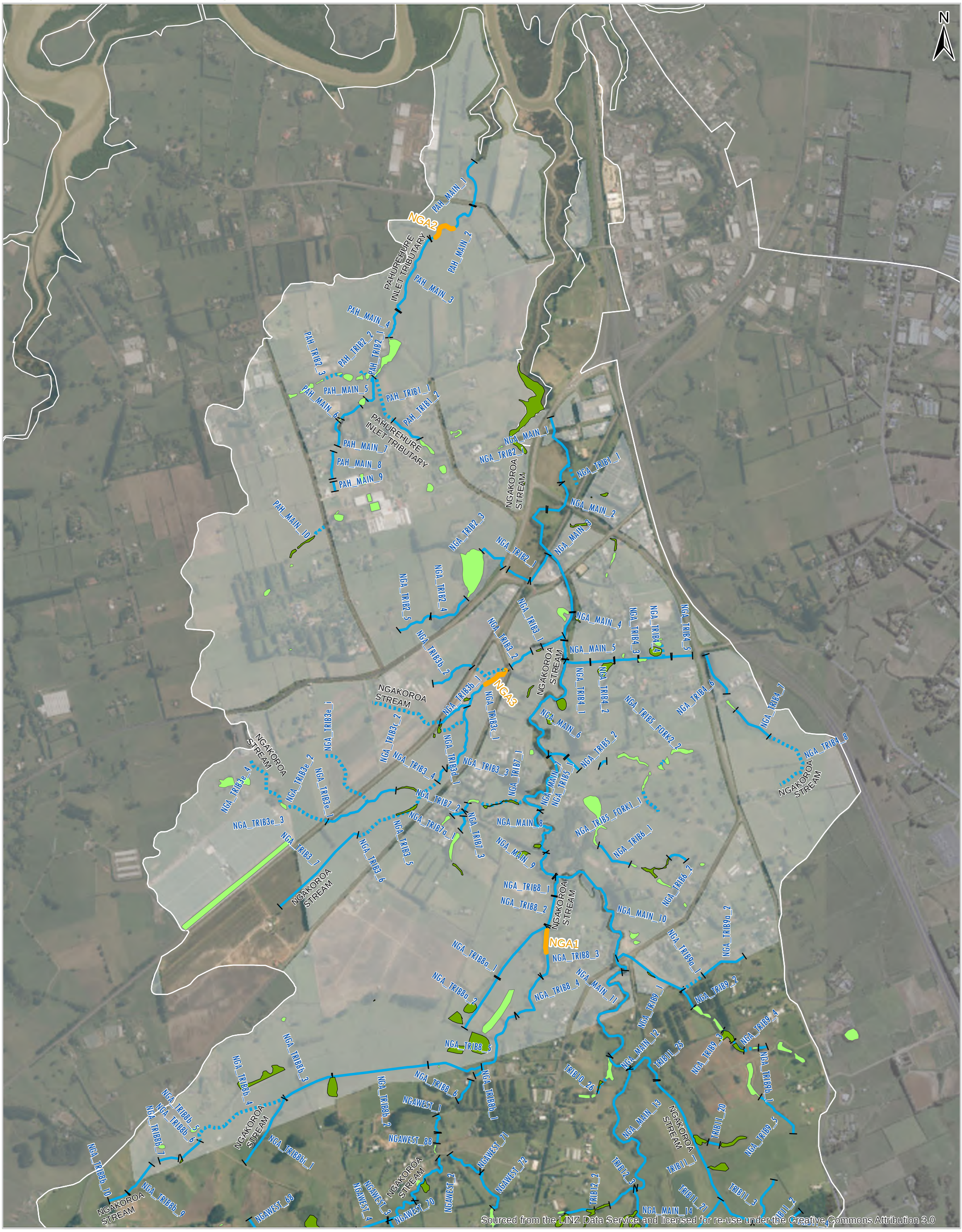
Map 1A - Overview Map



Ecoline (WAM)

- Permanent
- Intermittent
- Ephemeral

Wetland

- Natural
- Artifical

- Stormwater Catchments
- Future Urban Zone

- SEV Lines

Client AUCKLAND COUNCIL

Project **NGAKOROA WAR**

0 0.35 0.7 km

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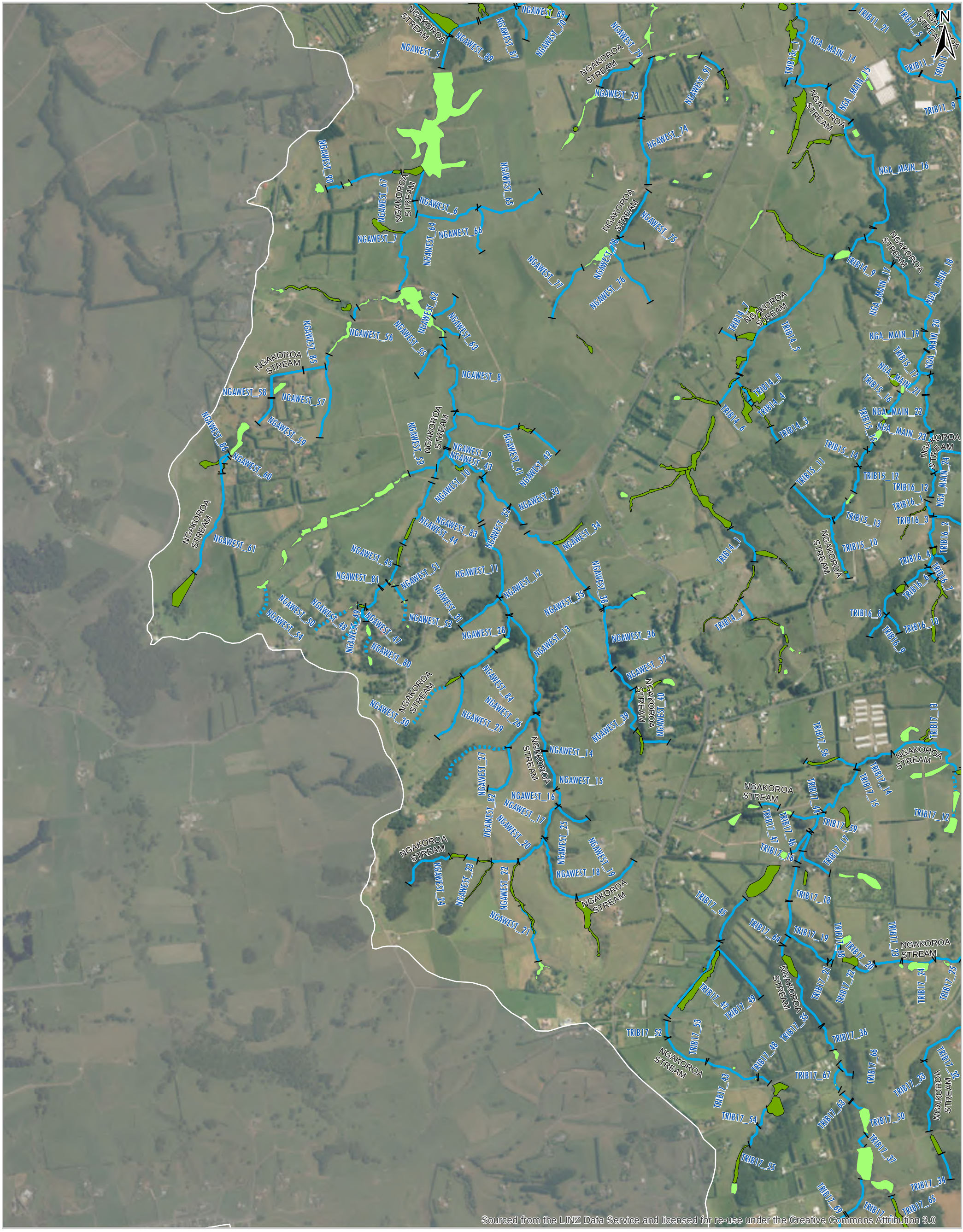
Map 1B - Overview Map



Ecoline (WAM)

- Permanent
- Intermittent
- Ephemeral

Wetland

- Natural
- Artifical

- Stormwater Catchments
- Future Urban Zone

- SEV Lines

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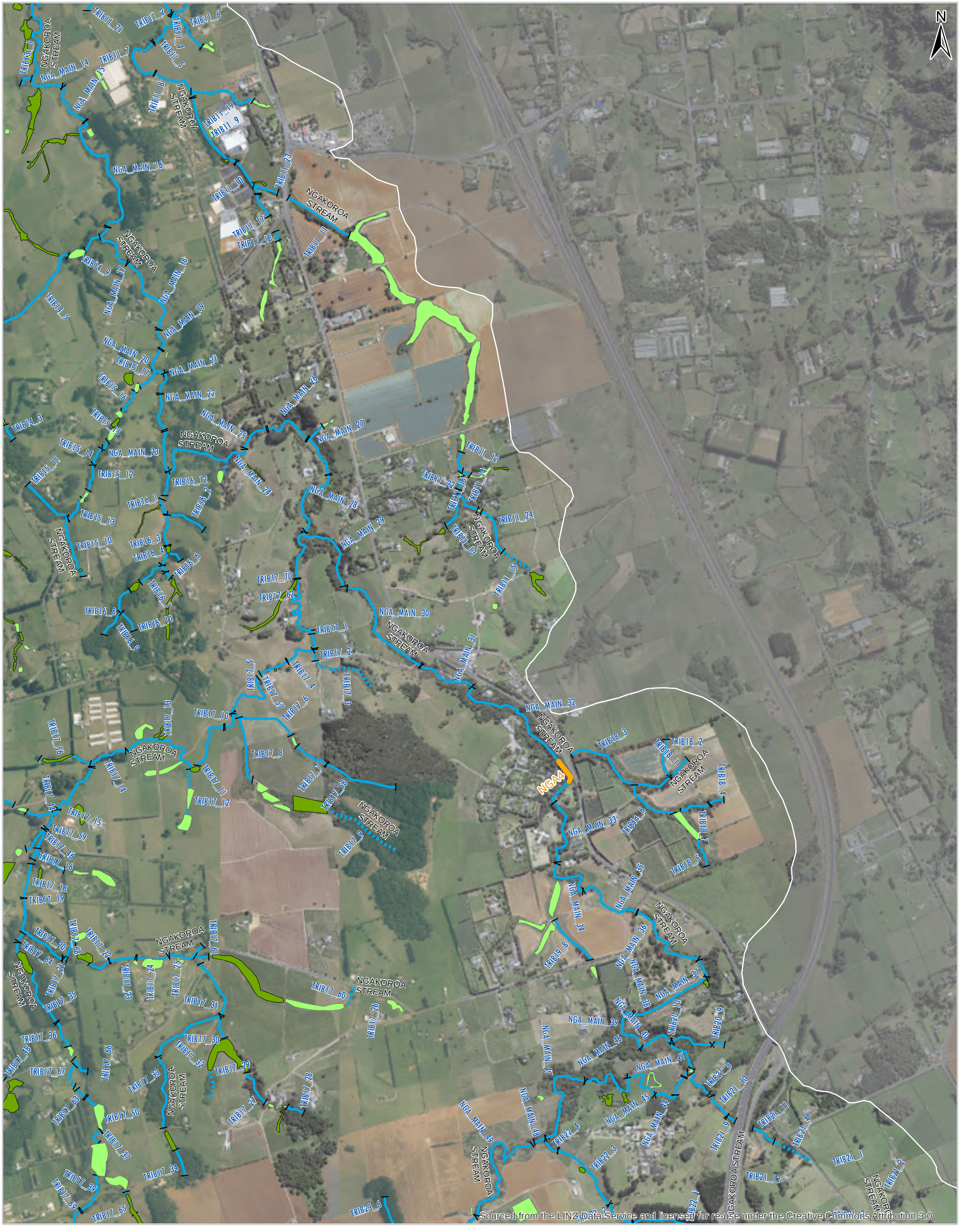
Map 1C - Overview Map



Ecoline (WAM)
- Permanent
- Intermittent
- Ephemeral

Wetland
- Natural
- Artifical

- Stormwater Catchments
- Future Urban Zone
- SEV Lines

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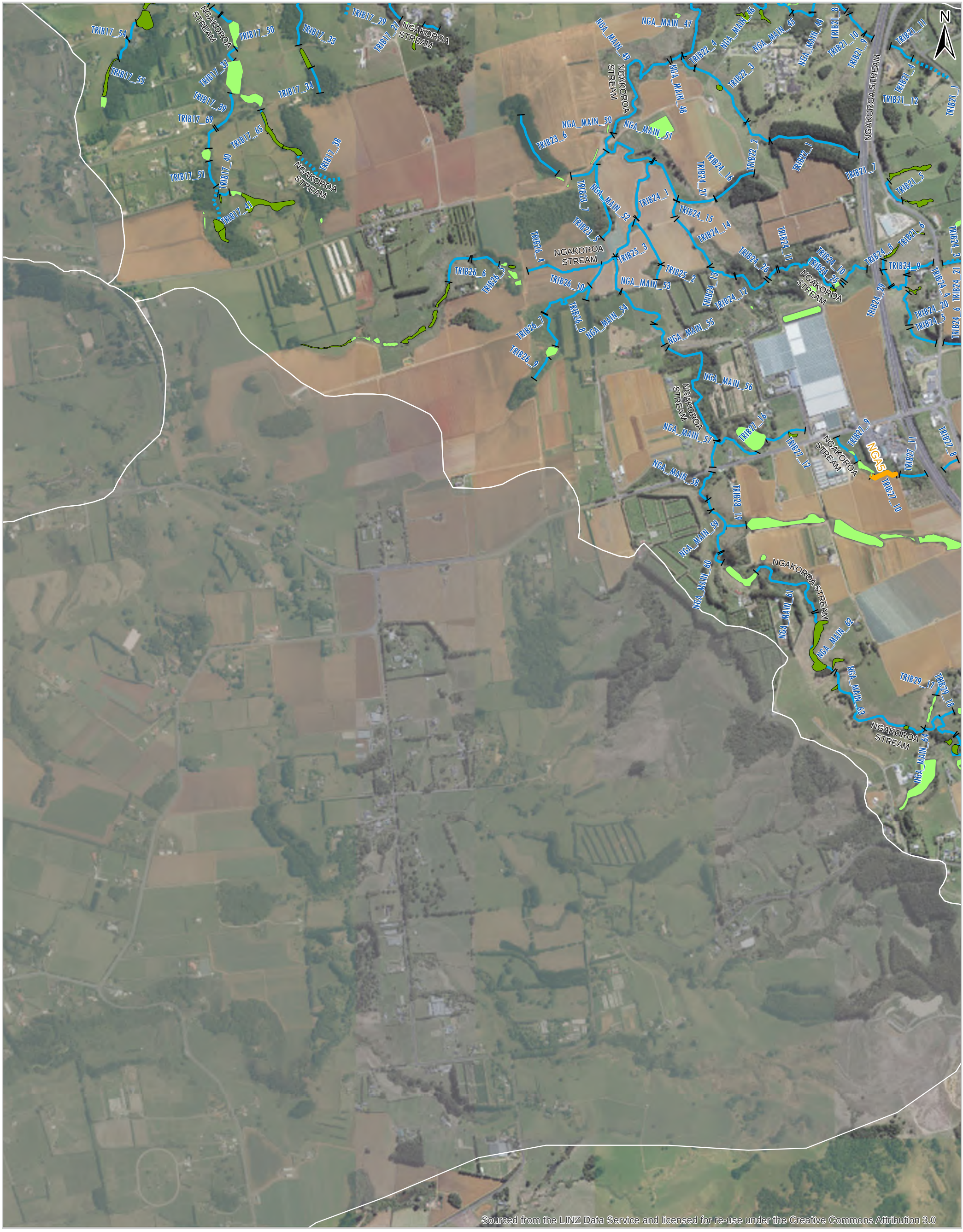
Map 1D - Overview Map



Ecoline (WAM)

- Permanent
- Intermittent
- Ephemeral

Wetland

- Natural
- Artifical

- Stormwater Catchments
- Future Urban Zone

- SEV Lines

Client AUCKLAND COUNCIL
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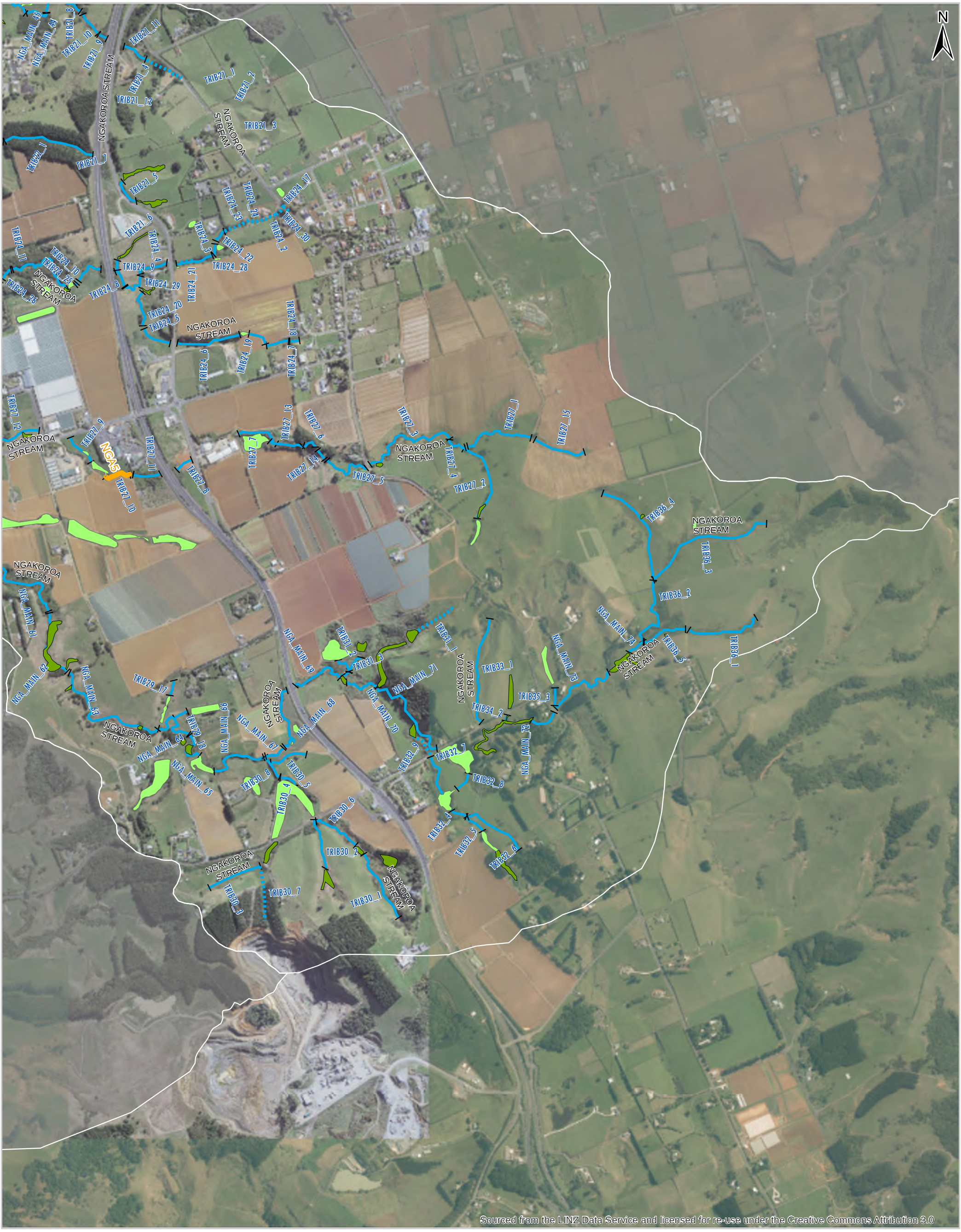
Map 1E - Overview Map



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Ecoline (WAM)

- Permanent
- Intermittent
- Ephemeral

Wetland

- Natural
- Artifical

- Stormwater Catchments
- Future Urban Zone

- SEV Lines

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Project **NGAKOROA WAR**

0 0.35 0.7 km

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Date 15 Jun 2018

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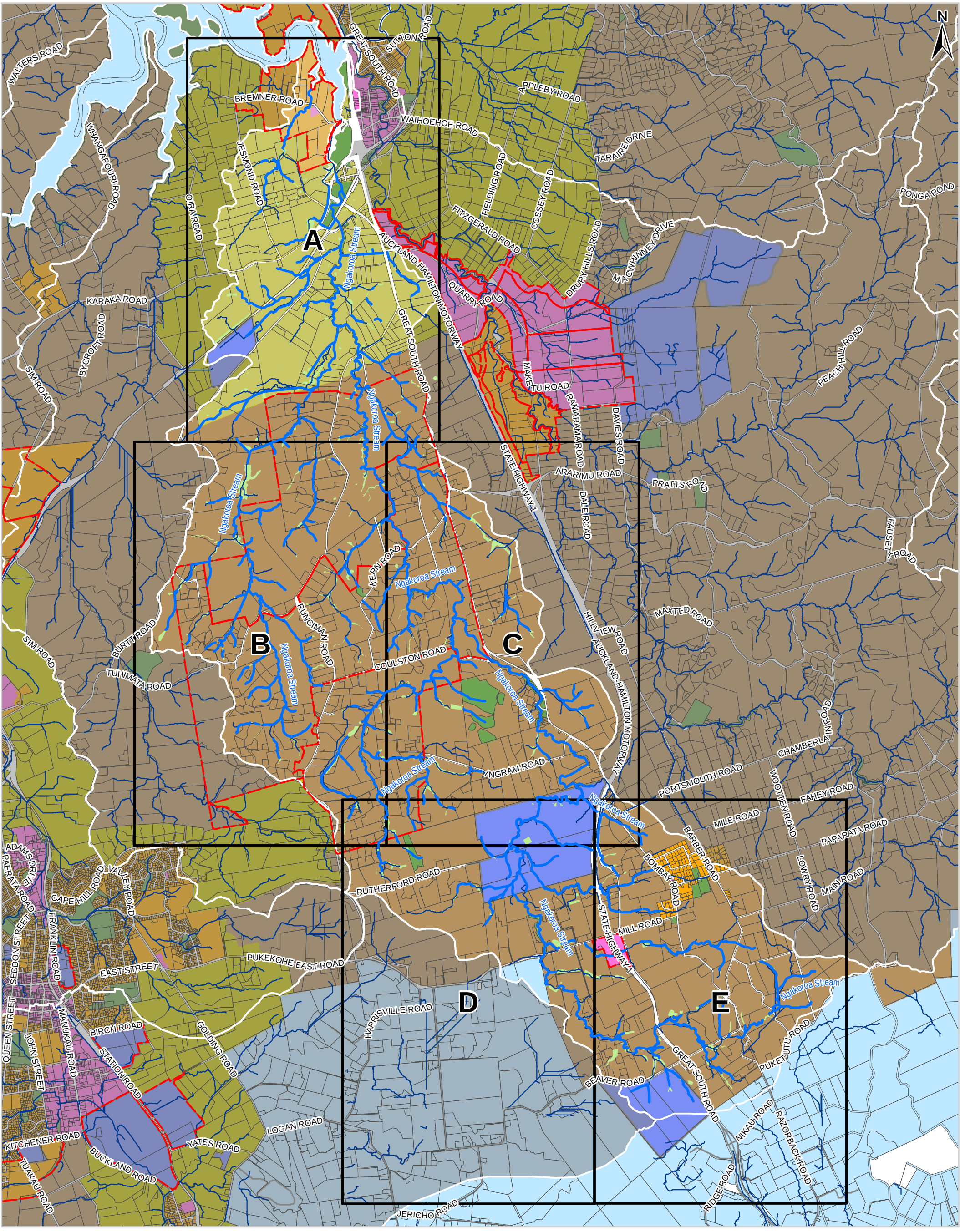
Map 2 - Catchment Landuse



AUP-OP Base Zone

- Business
- Open Space
- Special Purpose
- Rural
- Residential
- General
- New Growth
- Stormwater Catchments
- Ecoline
- Streams
- Wetland
- Future Urban Zone
- Precincts

Client AUCKLAND COUNCIL

Project **NGAKOROA WAR**

0 1,000 2,000 m

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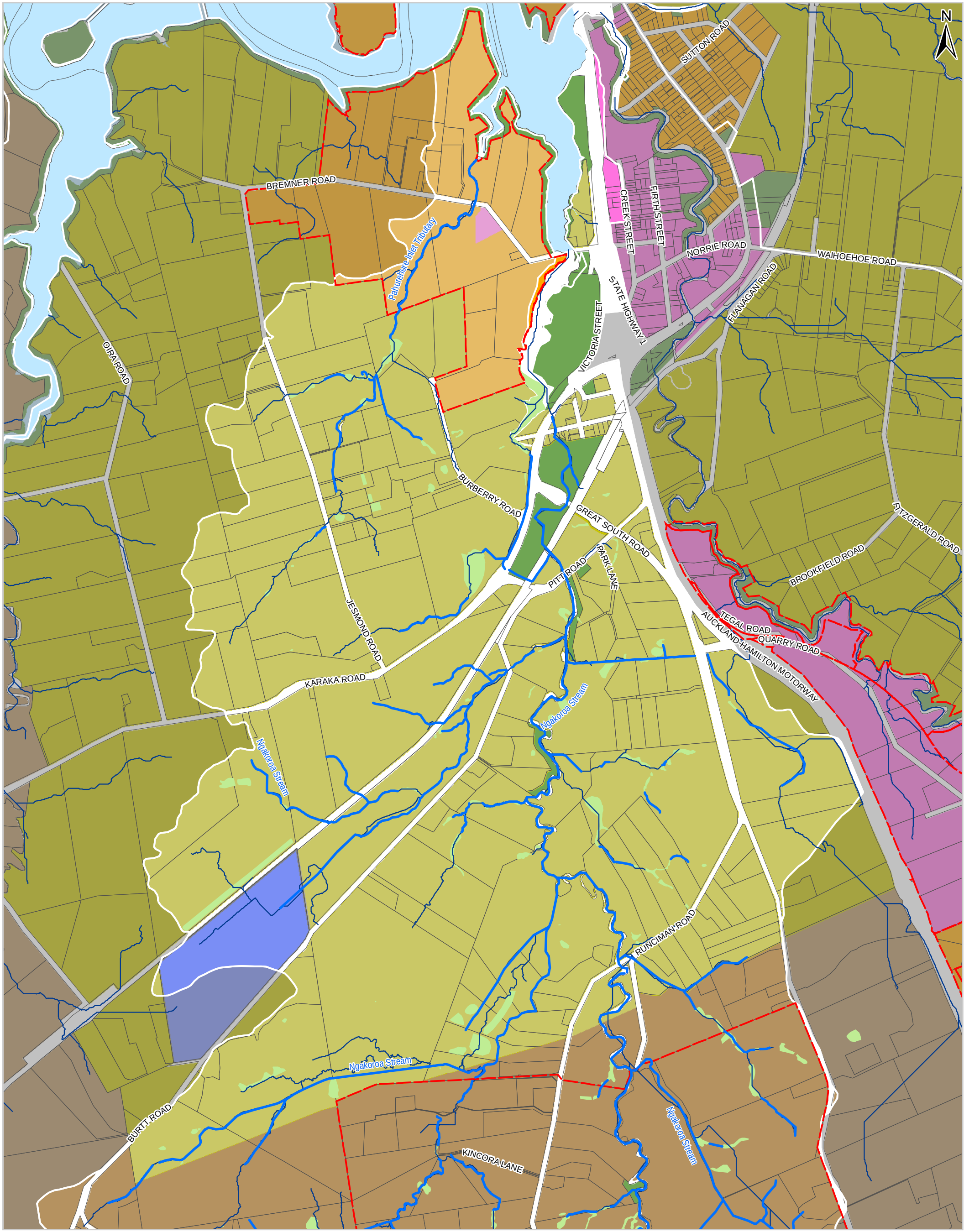
Map 2A - Catchment Landuse



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AUP-OP Base Zone

- Business
- Open Space
- Special Purpose
- Rural
- Residential
- General
- New Growth
- Stormwater Catchments
- Ecoline
- Streams
- Wetland
- Future Urban Zone
- Precincts

Client AUCKLAND COUNCIL

Project **NGAKOROA WAR**

0 330 660 m

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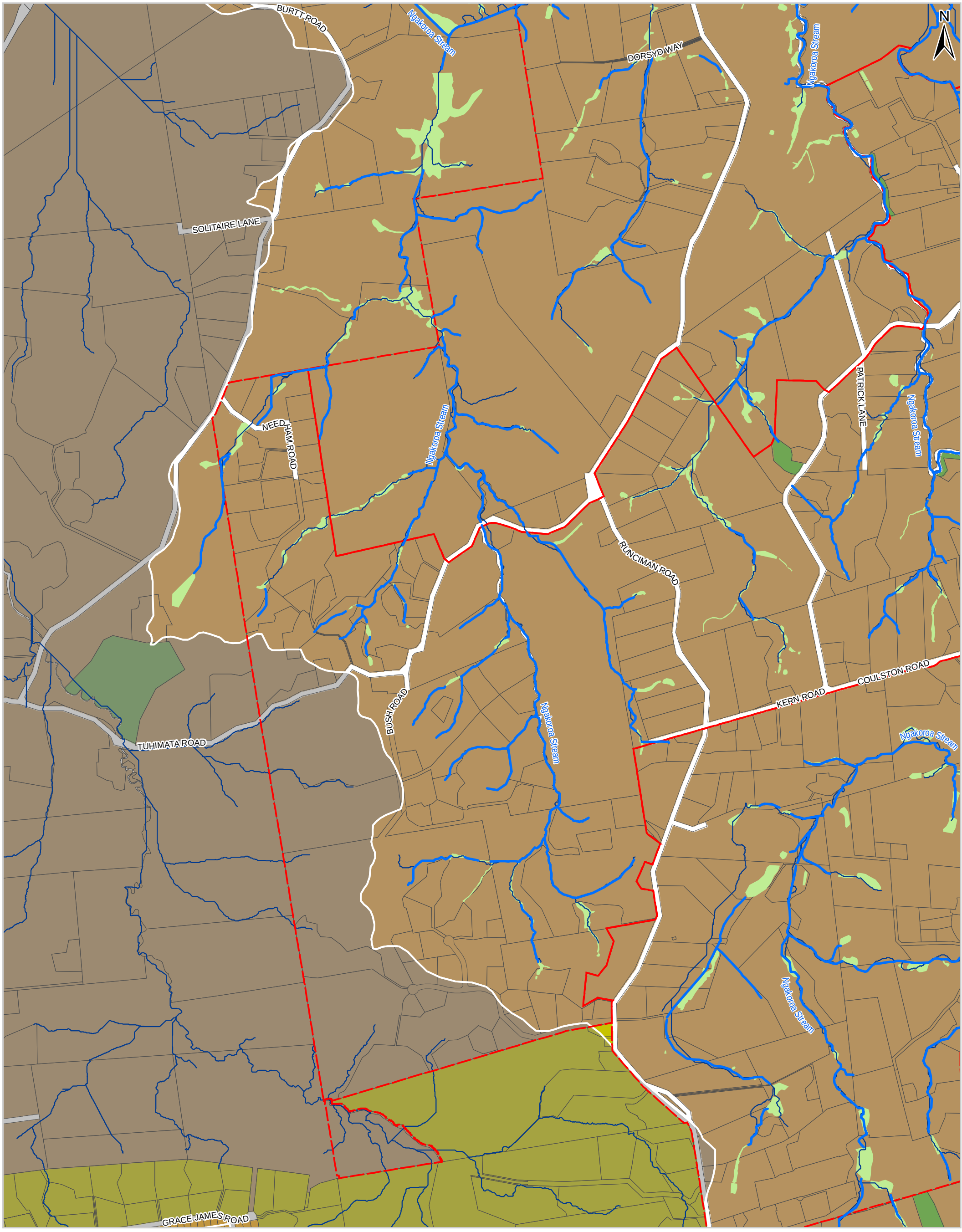
Map 2B - Catchment Landuse



AUP-OP Base Zone

- Business
- Open Space
- Special Purpose
- Rural
- Residential
- General
- New Growth
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- Ecoline
- Streams
- Wetland
- Future Urban Zone
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Project **NGAKOROA WAR**

0 330 660 m

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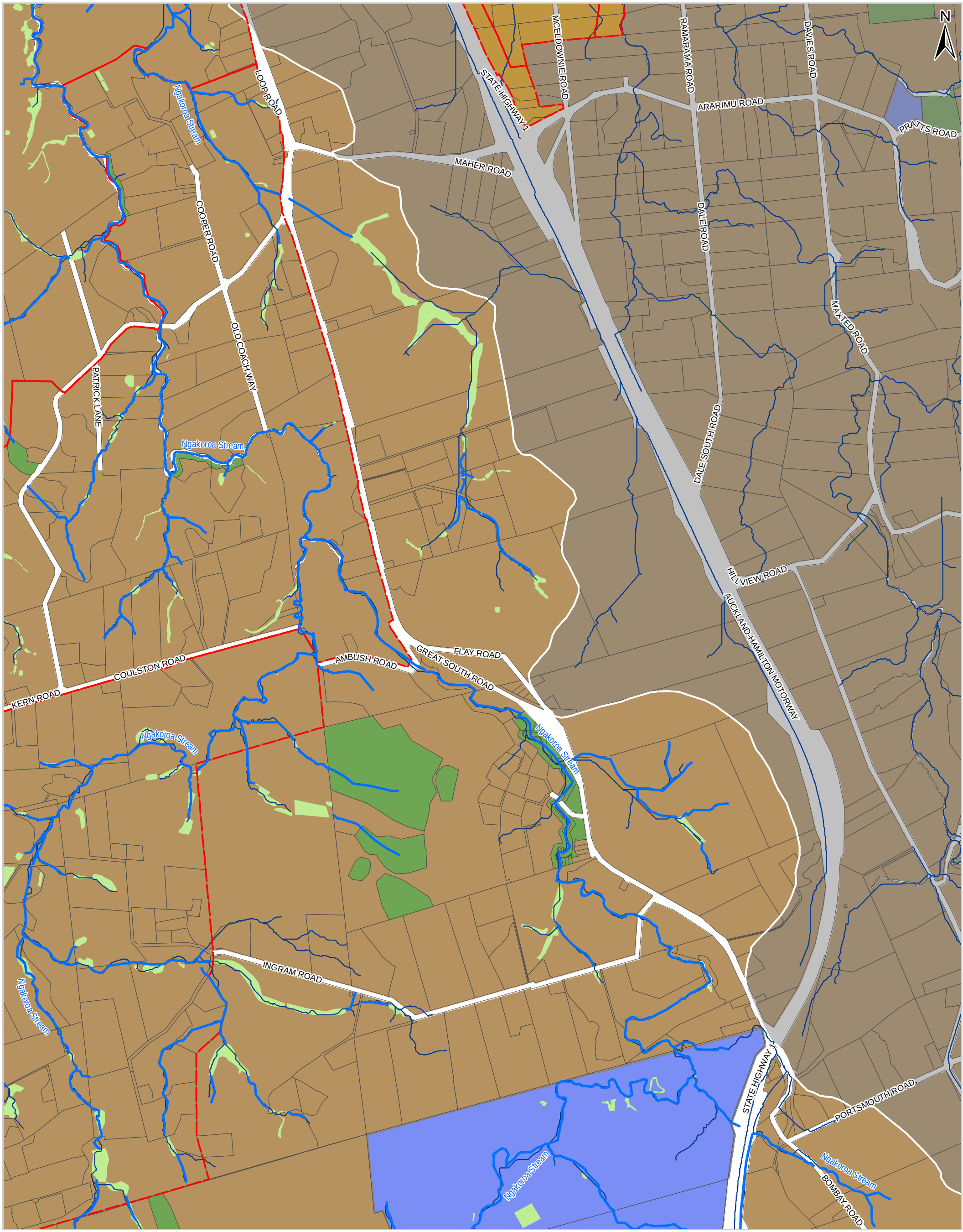
Map 2C - Catchment Landuse



AUP-OP Base Zone

- Business
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0 330 660 m

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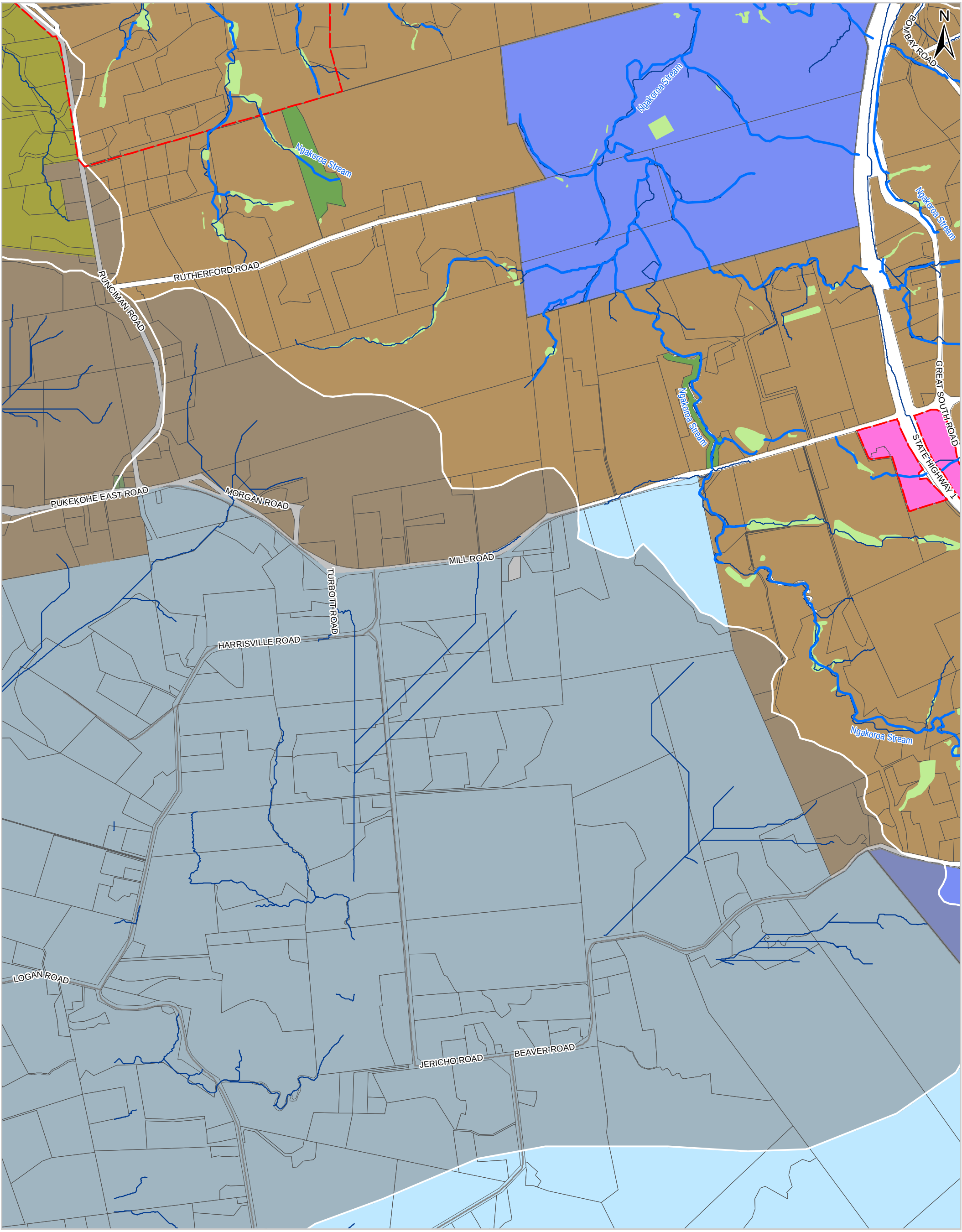
Map 2D - Catchment Landuse



AUP-OP Base Zone

- Business
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- Wetland
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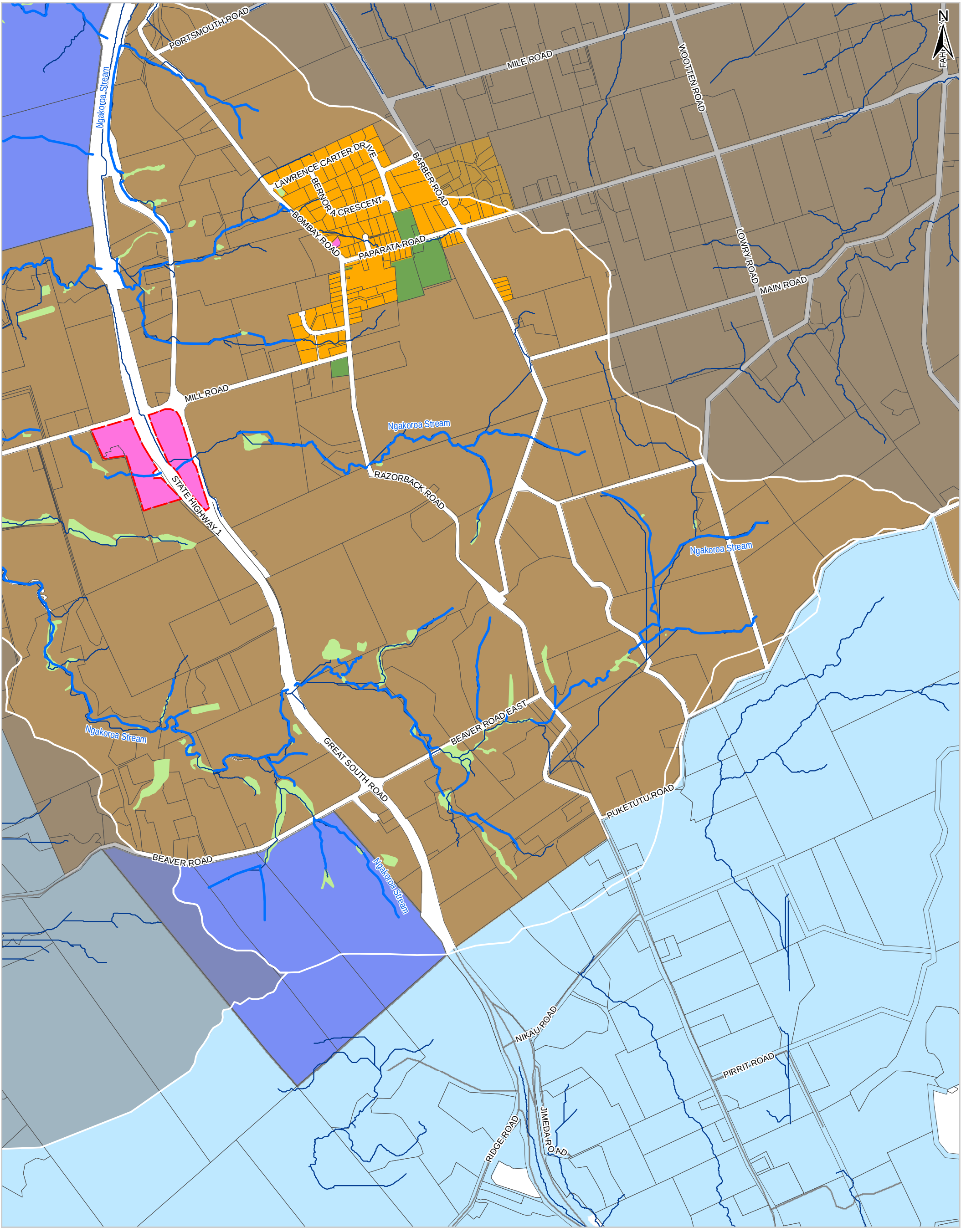
Map 2E - Catchment Landuse



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AUP-OP Base Zone

- Business
- Open Space
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- Rural
- Residential
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- Future Urban Zone
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Project **NGAKOROA WAR**

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