APPENDIX Z

Engineers & Consultants

Watercourse Assessment Report

Mangakōtukutuku Catchment

Final V4

Prepared for Hamilton City Council by Morphum Environmental Ltd

09 377 9779 | info@morphum.com | www.morphum.com

Engineers & Consultants

Document Control

Client Name: Hamilton City Council

Project Name: Mangakōtukutuku Watercourse Assessment Report

Project Number: P01235

Document: Mangakōtukutuku Catchment Watercourse Assessment Report

Revision History

Status	Date Issued	Author	Reviewed By	Released By
Draft	20/09/2017	E. Reeves, A. Rieger, K. Fredrick, H. Klein	R. Ingley	D. Young
Final V1	29/05/2018	E. Reeves, A. Rieger, K. Fredrick, H. Klein	R. Ingley	D. Young
Final V2	24/01/2019	R. Yeates, K. Parmar & S. McArthur	G. Lees, O. Ferrick	D. Young
Final V3	18/12/2019	J. McCord & R. Yeates	G. Lees	D. Young
Final V4	29/05/2020	J. McCord & R. Yeates	O. Ferrick	D. Young

Reviewed by:

Reviewer: Oliver Ferrick **Signature:** 

Released by:

Reviewer: Damian Young **Signature:** 

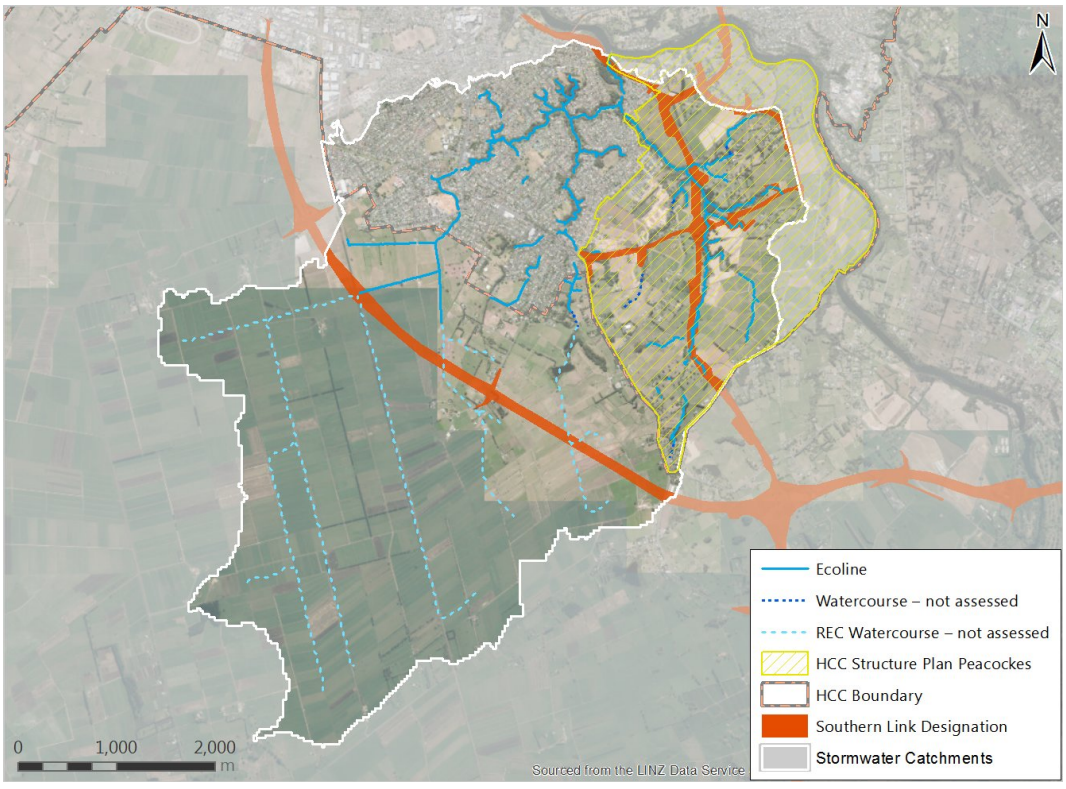
65 Victoria Street, Hamilton, 3204
09 377 9779 | info@morphum.com | www.morphum.com

Executive Summary

The purpose of the watercourse assessment and this report is to inform the Mangakōtukutuku integrated catchment management plan (ICMP), provide baseline data to consultants working in the catchment, support management of the watercourse and stormwater conveyance, and inform best practice Greenfield development in Peacocke sub-catchment. The report summarises the data collected, concept projects and management recommendations within the catchment.

The total length of open watercourse assessed is approximately 26 km. the field assessment was carried out between April 2017 – June 2017. The methodology followed in the Mangakōtukutuku watercourse assessment is the ICMP Receiving Environment Module developed by Morphum (Hamilton City Council [HCC], 2015). All interpretation of data should be used in conjunction with this document.

The Mangakōtukutuku catchment is approximately 2,677 ha and is located south of the Hamilton city centre. It is bound to the north and east by Peacocke catchment. Half of the hydrological catchment is within the Hamilton City Council (HCC) boundary. Mangakōtukutuku stream drains towards the north, with a single discharge point to the Waikato River downstream of Peacockes Road. An overview of the catchment is provided in the map below which identifies the extent of watercourse that was assessed. The farm drainage network, beyond the Hamilton City boundary, was not assessed and the NIWA River Environment Classification (REC) layer was used to identify the watercourse location.



Mangakōtukutuku catchment overview

Management zones

Future urban growth is proposed in the eastern sub-catchment of the Mangakōtukutuku which is currently rural land use. The Peacocke Structure Plan, as per the Partly Operative District Plan (PODP) at the time of writing this report, will rezone the rural area to residential with an indicative future reserve area focused around the gully and designated transport corridors. Furthermore, the designation of the New Zealand

Transport Authority (NZTA) Southern Links roading project in the eastern sub-catchment means that the Mangakōtukutuku catchment will experience a substantial change in land use over the next few decades. The new set of highways and linkage roads will help provide better access to support the planned growth in the catchment and link up several state highways.

The pressures and impacts of growth on the eastern Peacocke sub-catchment are of particular importance with the changing landuse where there is opportunity and consenting requirements to enhance part of the stormwater network. The main pressures and impacts identified in the eastern sub-catchment as a result of recent and proposed Greenfield development include:

- Change in land use and the associated contaminants of concern;
- Increased imperviousness and associated changes in hydrograph and impacts on watercourses, including increased potential for channel erosion and reduced base flows;
- Further potential barriers to fish passage with the development of more roads and associated culvert structures; and,
- Loss of riparian connectivity through the main gully channel.

Many of the existing reports prepared to support the development of the eastern catchment (including the Peacocke Structure Plan as per the PODP at the time of writing of this report) propose similar and overlapping recommendations. At a high level, these include:

- Protection and enhancement of ecological values including the protection of existing open watercourse, and planting of riparian corridors within the gully; and,
- Stormwater management including, at source, to manage effects on the receiving environment, to mitigate and regulate baseflows, and to maintain ecological and biodiversity values.

For the western and central sub-catchments some of the existing common pressures and impacts result from historical and existing land use including:

- Loss of riparian margin vegetation;
- Stock access to waterways;
- Contaminants entering waterways; and,
- Barriers to fish passage.

Erosion mitigation projects

The erosion mitigation projects areas identified in this watercourse assessment report are currently of concern, as well as areas within the Brownfields which may experience increased erosion in the future and provide remediation options to address localised issues. The 15 current erosion mitigation projects and 16 future erosion mitigation projects have been developed at a high level and consist of remediation types including; grade control, erosion planting and toe protection. The majority of the current projects are located along the main channels of the central and western Mangakōtukutuku sub-catchments. These subject reaches were identified as the most prone to erosion during the watercourse assessment, with several reaches showing high erosion scarring, and unstable undercut banks. These reaches currently receive flows from the stormwater network via several outlet structures and overland flow, with inputs and flows expected to increase with development in the area. It is recommended that erosion mitigation projects in these areas be prioritised.

Current erosion mitigation projects (EMP_1 to EMP_15) are largely based in the Brownfield development areas, with the exception of projects EMP_10 and EMP_11, which are located in Greenfield development areas in the eastern sub-catchment. The future erosion mitigation projects (EMP1_16 to EMP_31) are located in the Greenfields development areas in the eastern Mangakōtukutuku sub-catchment.

The total estimated costs including contingency of the physical works for the proposed erosion mitigation projects is approximately $12,532,000. It should be noted that the unit costs used to calculate these values

represent high-level estimates only. To define the specifics of downstream impacts, including costs and methods, will require further investigation into the stormwater management in the catchment and be informed by ongoing monitoring of these erosion sensitive reaches. It is therefore recommended that identification of watercourse works and pricing is undertaken as part of the ICMP.

These erosion mitigation projects and their high-level costs is summarised in the table below and expanded on in section 5.2 of this report. Refer to Appendix 1, Map 5 for the location of these sites.

Summary of erosion mitigation projects in the Mangakōtukutuku catchment

Project ID	Proposed erosion mitigation works	Total including 20% Contingency
EMP_01	• Provide toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Replacement of weeds (*tradescantia* and Japanese walnut) with natives and consideration of staged willow removal	$ 1,088,000
EMP_02	• Keystone boulders to provide toe protection	$ 156,000
EMP_03	• Provide toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Replacement of weeds such as willows, *tradescantia* and Japanese walnut with natives	$ 581,000
EMP_04	• Provide toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Replacement of weeds such as willows, *tradescantia* and Japanese walnut with natives • Mitigate fish barrier to climbing species at culvert outlet beneath path crossing MGk_C_Trib1_2 by installing a fish ladder or spat rope.	$ 1,037,000
EMP_05	• Increased channel heterogeneity of cobbles and rocks to support fish habitat • Significant weeding and replanting with natives • Naturalisation/removal of the lined channel along MGK_W_Trib5_7	$ 632,000
EMP_06	• Weeding and planting of natives 5m either side of reach to support the regraded banks	$ 77,000
EMP_07	• Toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Planting of native understory along regraded banks	$ 356,000
EMP_08	• Toe protection to banks • Regrading of banks • Planting of native understory along regraded banks	$ 341,000
EMP_09	• Newbury Rock riffle • Keystone boulders • Grade control	$ 166,000
EMP_10	• Weeding and planting of native understory along regraded banks	$ 84,000

EMP_11	• Toe protection along channel • Weeding and planting of natives 5m either side of reach to support the regraded banks	$ 438,000
EMP_12	• Bank batter to regrade banks to a 3:1 slope • Erosion planting • Retaining • Toe protection	$ 164,000
EMP_13	• Bank batter • Erosion planting • Toe protection	$ 883,000
EMP_14	• Bank batter • Erosion planting • Toe protection	$ 868,000
EMP_15	• Bank batter • Erosion planting	$ 26,000
SubTotal		**$ 6,897,000**
EMP_16	• Erosion planting • Bank regrading • Toe protection • Grade control structures	$1,164,000
EMP_17	• Bank batter • Toe protection • Grade control structures	$259,000
EMP_18	• Erosion planting • Bank regrading • Toe protection • Grade control structures	$514,000
EMP_19	• Erosion planting	$116,000
EMP_20	• Erosion Planting • Bank batter • Grade control	$191,000
EMP_21	• Bank batter • Toe protection	$192,000
EMP_22	• Erosion planting • Bank batter	$289,000
EMP_23	• Erosion planting • Bank Batter • Toe protection	$215,000
EMP_24	• Bank batter • Toe protection	$534,000
EMP_25	• Erosion planting • Bank batter • Toe protection	$397,000
EMP_26	• Erosion planting • Bank batter	$151,000
EMP_27	• Bank batter • Toe protection	$617,000
EMP_28	• Erosion planting • Bank batter	$653,000

	• Toe protection	
EMP_29	• Erosion planting • Bank batter	$145,000
EMP_30	• Erosion planting • Bank batter • Toe protection	$106,000
EMP_31	• Erosion planting • Bank batter • Toe protection	$92,000
Subtotal		**$ 5,635,000**
Total		**$ 12,532,000**

Enhancement opportunity projects

A total of 19 enhancement opportunities have been proposed within the Mangakōtukutuku catchment. These projects highlight enhancement opportunities for the developer, private land owners and Council, to increase the ecological and amenity values of the watercourse, whilst enhancing flow conveyance and improving resilience against further changes to surrounding land use. The estimated cost of the enhancement projects is approximately $ 35,282,000. The final costings presented in this report should be considered as indicative only with further refinement required at the detailed design stage. The purpose of the costs provided in this report is to indicate relative costings for the purpose of decision making. Refer to Appendix 1, Map 6 for the location and spatial extent of these proposed enhancement opportunities.

The enhancement opportunities focus primarily on enhancement planting along stream corridors. The majority of enhancement opportunities focus on ecological planting in the Eastern sub-catchment. These projects can be incorporated into the Southern Links implementation works, as part of an Ecological Monitoring and Management Plan (EMMP), as required by the conditions of the Southern Links designation. The consent condition for the designation require 11.8 hectares of restoration. A full cost estimate for projects EO17 – EO19 has not been provided due to the scale and complexity of the proposed works. These projects highlight the opportunity to naturalise ponds. It is recommended that an options assessment and landowner liaison is undertaken prior to cost estimates being undertaken.

Recommendations for the ICMP

Through the development of this Watercourse Assessment Report, the requirements for additional investigations and considerations have been identified to inform the wider ICMP. These include:

1. Hydrogeology investigation in the eastern Peacocke sub-catchment to understand groundwater processes of springs and seepages with objectives to maintain baseflows for ecological outcomes and inform geotechnical risk.
2. Further investigation into the interaction between increased volumes and the erosion risk in the eastern Peacocke sub-catchment.
3. Flood storage within the gully and impact on road crossings including investigating issues such as inadvertent dam failure risk under flood conditions.
4. Top of gully bank management including possible set back of development for geotechnical risk and management of stormwater for overland flow.

5. Management and control of stormwater discharge within the gully including outfall erosion protection.

The Mangakōtukutuku Watercourse Assessment and this report provides Hamilton City Council with valuable knowledge and understanding of the existing state of the Mangakōtukutuku watercourse.

Contents

Tables

1.0 Introduction

1.1 Overview

Hamilton City Council (HCC) has been developing integrated catchment management plans (ICMPs) to support management of catchments, facilitate growth and to comply with Hamilton City Council's Comprehensive Stormwater Discharge Consent (CSDC).

In 2015, Waikato Regional Council approved the first ICMP. During this time, a set of method guidance 'modules' were developed to help standardise data collection, modelling, data presentation and reporting for future ICMPs. One of these modules is the Receiving Environment Module [REM] which sets out a baseline assessment methodology for watercourses (HCC, 2015).

This report and associated field assessments have been conducted as per the REM and to support the development of the Mangakōtukutuku ICMP.

1.2 Scope

Morphum Environmental Ltd (Morphum) was engaged by the Hamilton City Council (20/12/2016) to undertake a watercourse assessment of the Mangakōtukutuku catchment in Hamilton. The scope included a walkover assessment, the development of this report, and delivery of all spatial datasets collected during the assessment. This report summarises the data collected, identifies concept projects and management recommendations within the catchment.

The purpose of the watercourse assessment and report is to inform the Mangakōtukutuku ICMP, provide baseline data to consultants working in the catchment, support existing management of the ecological values of watercourses and stormwater conveyance, and inform best practice Greenfield development in the Peacocke sub-catchment.

This report has primarily been informed by rapid field assessment undertaken in accordance with the ICMP Receiving Environment Module method (see section 3.0). A literature review of previous assessments undertaken in the catchment was outside the scope of this report.

The scope of works included the following:

- Field assessment of 26 km of open watercourse within the Hamilton City boundary.
- Preparation of a watercourse assessment report including issues and opportunities for enhancement.
- The identification of erosion mitigation projects to address existing and potential future erosion issues within the catchment.
- Selection and development of enhancement opportunities and potential management options and actions.

The extent of the watercourse assessment was defined by Morphum and agreed with Council prior to the assessment survey being conducted. It should be noted that an extensive farm drainage network exists upstream of the Hamilton City boundary which was not part of this assessment scope. In some instances, sections of watercourse within the scoped extent were not assessed where consent to access was not provided by the land owner. The extent of the watercourse assessed is summarised in the catchment overview map in Appendix 1.

1.3 Reach Naming Convention

The Mangakōtukutuku Watercourse Assessment Report provides the context for the survey, summary of findings, watercourse management zones and concept projects for consideration in the Mangakōtukutuku ICMP.

The document provides references to reach/tributary using a tributary code. The numbering convention is determined based on the number of tributaries entering the main reach throughout the sections. For Example:

- MGK_C_Main_1 is the 1st reach of the main channel in the central Mangakōtukutuku sub-catchment.
- MGK_E_Trib3_5 is the 5th reach of the third tributary (heading upstream) of the eastern Mangakōtukutuku sub-catchment.
- MGK_W_Trib1_Fork1_ is the first fork of the 1st tributary (heading upstream) of the western Mangakōtukutuku sub-catchment.

The tributary codes are mapped against the reaches in Appendix 1

2.0 Catchment Overview

2.1 Catchment Location and Drainage

The Mangakōtukutuku catchment is approximately 2,677 ha in area and is located south of Hamilton's city centre. It is bound to the north and east by Peacocke catchment and Waitawhiriwhiri catchment to the west. Half of the hydrological catchment is within the Hamilton City boundary (subject catchment). Mangakōtukutuku stream drains towards the north, with a single discharge point to the Waikato River below Peacockes Road. The catchment overview map is provided in Figure 1.

Mangakōtukutuku is one of the largest Hamilton gully systems in the region and is identified as a 'gully reserve network' under the Gully Reserves Management Plan (Turner & Craig, 2007). The gully system is divided into three main sub-catchments:

- The west sub-catchment is defined as the area upstream of the Manor Place/Keitha Place cul de sac. The land use within the subject catchment is predominately residential with several commercial pockets and one area of industrial land use to the west. The land use in the wider catchment, in the Waipa district is rural and is made up of a significant farm drainage network. The area has previously been referred to as the Deanwell sub-catchment.
- The central sub-catchment is defined as the area upstream of the Lewis Street and Bruce Ave corner. The land use within Hamilton City boundary is predominantly residential and the area has previous been referred to as the Glenview sub-catchment. The land use in the wider catchment is rural.
- The east sub-catchment is defined as the area upstream of Waterford Road. The catchment is rural and is located within the Peacocke structure plan. The structure plan will rezone the entire rural area to low-medium density residential. Furthermore, the designation of the Southern links roading project in the eastern sub-catchment identifies this area to be one that will experience a high degree of change over the next few decades.

The Mangakōtukutuku catchment is characterised by steep gullies with extensive confined floodplains and seepage wetlands on the banks above the floodplain. Much of the gully network, in the western and central sub-catchment, has a consistent riparian width set back from the gully. There is a small number of existing road crossings of the gully network where the watercourse has been culverted.

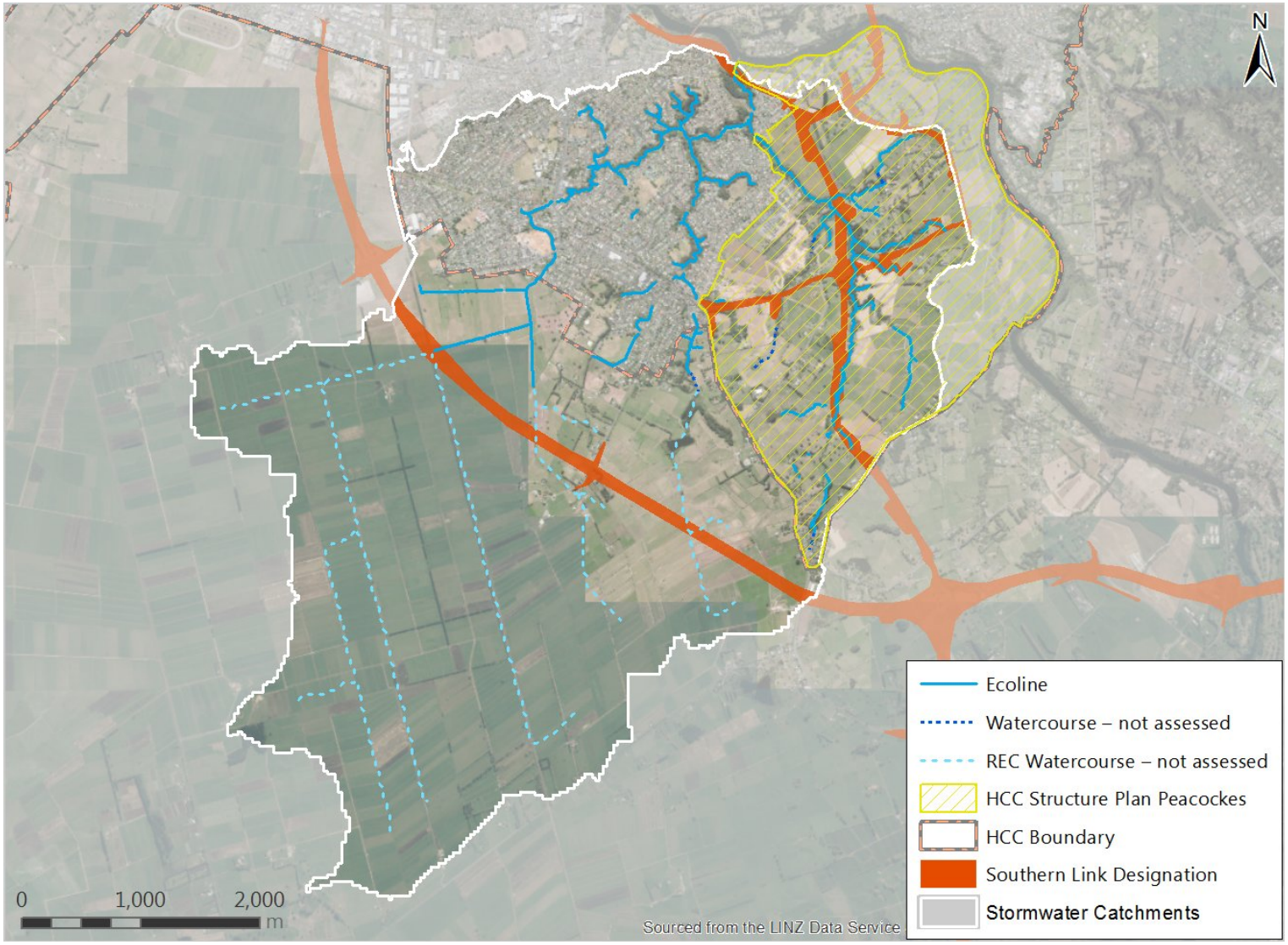


Figure 1: Mangakōtukutuku Catchment Overview.

2.2 Future Land Use

Hamilton is currently experiencing rapid urban expansion through infill housing and new developments on the city fringes. Most of the city fringe growth is concentrated around the four HCC Structure Plans detailed in the Partly Operative District Plan (PODP) (HCC, 2015) these being; Rototuna, Rotokauri, Ruakura and Peacockes.

The eastern branch of Mangakōtukutuku is within the Peacocke Structure Plan area. This area of land was incorporated into Hamilton City in 1989 from Waipa District Council with the main purpose to provide an area for growth and eventually a community hub. The dominant zoning will be residential with an indicative future reserve zoning approximately 20 m from centre of the Mangakōtukutuku stream. Walkways and cycle ways will allow for increased access to gully systems and the river corridors. Residential development has started to occur in the western edge of the structure plan around Dixon Road.

The Peacocke Structure Plan objectives and policies related to the Mangakōtukutuku Gully are provided below:

6. Objective: "Protect and enhance significant natural areas."
7. Policies:

   *"**3.4.1.1a** Protect the physical integrity and ecological and stormwater function of the Mangakōtukutuku Gully and Waikato River margins.*

   ***3.4.1.1b** Provide an undeveloped open space buffer zone beyond the top edge of the Mangakōtukutuku Gully and Waikato River to improve legibility from all parts of the growth cell.*

   ***3.4.1.1c** Encourage lower density development (lot sizes of 800m^2+) along the gully network.*

   ***3.4.1.1d** Provide for revegetated gullies and river margins.*

   ***3.4.1.2a** Provide green corridors between the major arms of the Mangakōtukutuku Gully and Waikato River.*

   ***3.4.1.4d** Seek ways to reduce the impact of major movement barriers such as major arterial roads, the Mangakōtukutuku Gully and the Waikato River".*

The NZTA Southern Links project is also a significant part of the changing land use occurring in the Mangakōtukutuku catchment. The new set of highways and linkage roads will help provide better access to support the planned growth in the catchment and link up several state highways. The designation for the new set of highways is provided in Figure 1. As part of the designation conditions issued by HCC (HCC, ND), an Ecological Management and Monitoring Plan is required to be prepared which includes identifying at least 11.8 ha of land for restoration. A selection of the projects identified in this report will be incorporated into Southern Links implementation works as part of the Ecological Management and Monitoring Plan. Preparation of this Plan in underway at the time of writing.

2.3 Ecological Values

The Mangakōtukutuku catchment is one of the largest gully systems within the Hamilton City boundary. The central and western sub-catchments within the subject catchment have consistent riparian extent along the gully banks and the catchment has been identified by several regional studies for its ecological values.

The Mangakōtukutuku catchment is noted for its high biodiversity (EPT taxa richness, and fish diversity), and good water quality (MCI scores) compared to the other sampled locations (Kirikiriroa and

Mangaonua, Waitawhiriwhiri and Te Awa O Katapaki) (Aldridge and Hicks, 2006; Collier *et al*. 2009). Native fish observed include torrentfish, banded kokopu, giant kokopu, koura, smelt, and shortfin and longfin eels (Aldridge and Hicks, 2006).

Environment Waikato (now Waikato Regional Council) undertook 30 stream ecological valuations (SEVs) across Hamilton watercourses in 2009 (Collier *et al*., 2009). Ten of these were located in the Mangakōtukutuku catchment. Three SEV sites were located in the western sub-catchment, four in the central sub-catchment, two in the eastern sub-catchment and one along the main channel near the confluence with the Waikato River. The SEV scores ranged from 0.42 to 0.62, indicating fair – good ecological values.

The Mangakōtukutuku has the richest native fish assemblages in the Hamilton City area (not including the Waikato River itself) with records of torrentfish, banded kokopu, giant kokopu, koura, smelt, shortfin and longfin eel (Aldridge and Hicks, 2006).

There are a number of significant natural areas, significant trees, and cultural sites identified as part of the PODP at the time of writing this report. These significant areas are discussed below and mapped in Figure 2.

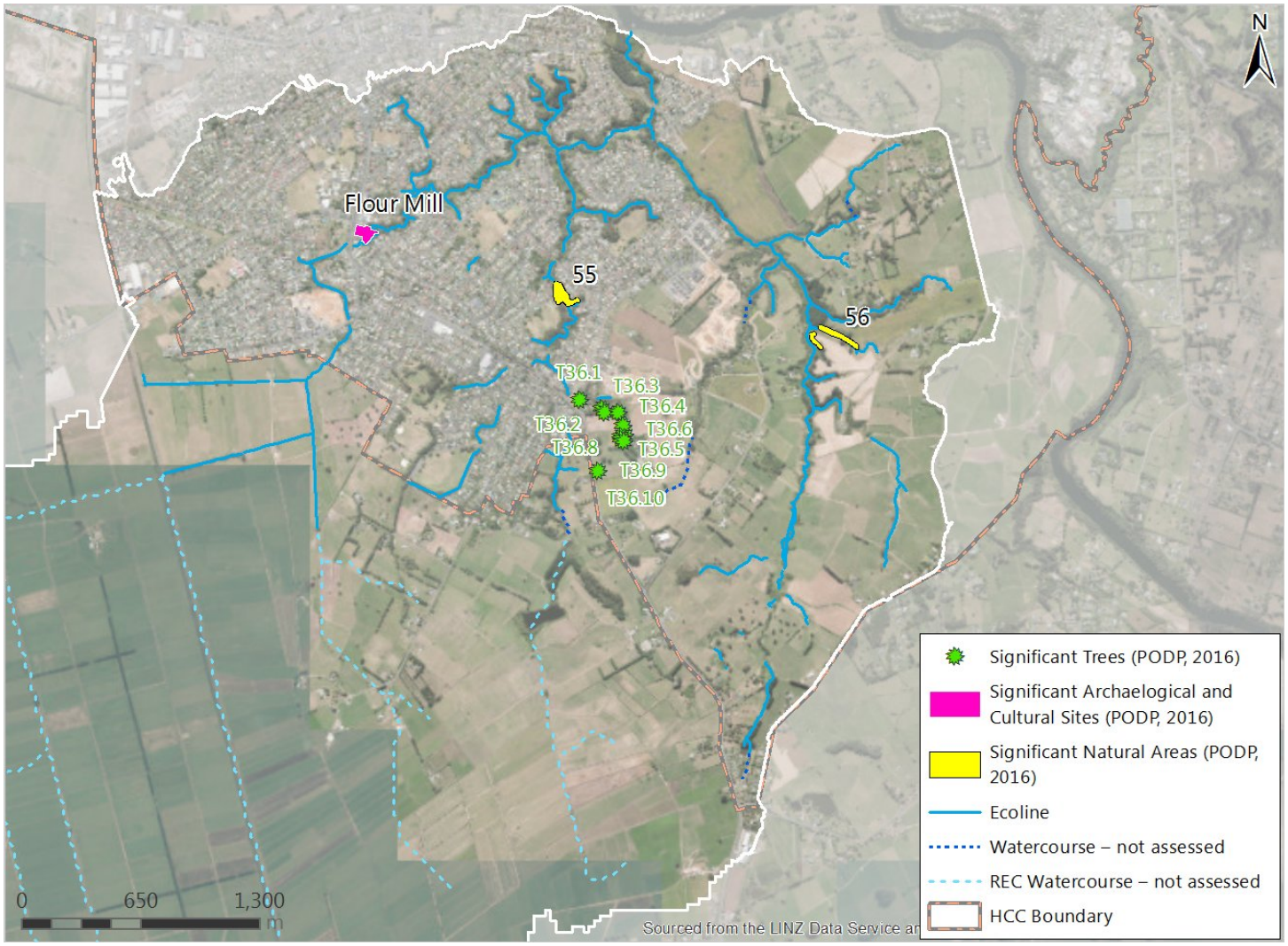


Figure 2: Partially Operative District Plan Significant Sites (Ecoline is area surveyed as part of this watercourse assessment).

2.3.1 Significant Natural Area

There are two sites identified as Significant Natural Areas in the Mangakōtukutuku catchment under the WRC Policy Statement criteria for ecological significance (Table 1). One of the key sites (SNA 56) is located in the eastern sub-catchment along MGK_E_Trib4_1 which is made up of two locations. The second location (SNA 55) is located in the central sub-catchment along MGK_C_Main_3. Both areas were identified due to their rare or exceptional representation of species (criterion 10), SNA 56 is also noted for the provision of habitat for threatened or endemic species (criterion 3).

Table 1: Significant Natural Areas in the Mangakōtukutuku Catchment (Schedule 9C, Volume 2, Appendix 9, PODP 2016).

SNA No.	Name	Main Vegetation Type	Criteria	Area (m^2)
55	Mangakōtukutuku Gully, Te Anau Park	Eucalyptus, Pine (Kahikatea)/ Treefern, Privet forest	10	6,095
56	Kanuku Patch, Mangakōtukutuku Gully, Peacocke	Kanuku/Privet, Grey Willow forest	10, 3	956,3,070

2.3.2 Significant Trees

Ten significant trees were identified in the Mangakōtukutuku catchment as per the significant trees layer from the 2016 PODP (Table 2). All of these are located within close proximity to each other within the central sub-catchment along MGK_C_Fork2_Trib1_1 near the Carbourne wetlands at Northview Farm – 3019 Ohaupo Road. It should be noted that these areas are situated in close proximity to the site of the proposed Southern Links highway.

Table 2: Significant Trees identified in Mangakōtukutuku Catchment (Schedule 9D, Volume 2, Appendix 9, PODP 2016).

Reference Number	Common Name	Botanical Name
T36.1	English Oak	*Quercus robur*
T36.2	Pin Oak	*Quercus palustris*
T36.3	Pin Oak	*Quercus palustris*
T36.4	Pine	*Pinus* sp.
T36.6	Fir	*Abies* sp.
T36.5	Pin Oak	*Quercus palustris*
T36.7	London Plane	*Platanus acerifolia*
T36.8	Pin Oak	*Quercus palustris*
T36.9	Eucalyptus	*Eucalyptus* sp.
T36.10	Elm	*Ulmus*

2.3.3 Archaeological, Historic or Cultural Heritage Sites

Only one significant archaeological or cultural heritage site is identified in the PODP within the Mangakōtukutuku catchment (Table 3). The site is a historic flour mill located within the western sub-catchment along MGK_W_Main_8, downstream of Ohaupo Road near Urlich Ave.

Table 3: Significant Archaeological, Historic and Cultural Sites as per the PODP 2016.

Name	Type	Site No.	NZ Archaeological Association number
Mangakōtukutuku	Flour Mill	A104	S14/102

2.3.4 Waikato River Bank and Gully Hazard Area

The PODP identifies areas near the Waikato River and gullies that may have some hazard associated with them. Chapter 22 discusses natural hazards and section 22.2.1 states:

"New use and development which is vulnerable to the adverse effects of land instability shall avoid the Waikato Riverbank and Gully Hazard Area, where the adverse effects and risks have not been minimised to an acceptable or tolerable level."

Objectives and Policies in chapter 22 that relate to the Waikato River Corridor and Gully Systems are provided below:

21.2.1a *"An integrated, holistic and co-ordinated approach to management shall be used to protect, enhance and restore the natural, physical, cultural and historical resources and character of the river corridor and gully system. The management approaches referred to in 21.2.1a include significant natural areas, scheduled cultural sites, the High, Medium and Low Flood Hazard Areas, Temple View Flood Hazard Area, Culvert Block Flood Hazard Areas, the Waikato Riverbank and Gully Hazard Area and Open Space Zone."*

Existing development practices in Hamilton City generally require approximately 6 metres set back approximately from the Waikato River Bank and Gully Hazard Area (as per PODP). Increasing the length of this set back should be considered as part of the ICMP investigations and is discussed further as part of the management objectives. The Waikato River Bank and Gully Hazard Area for the Mangakōtukutuku catchment are displayed in Figure 3.

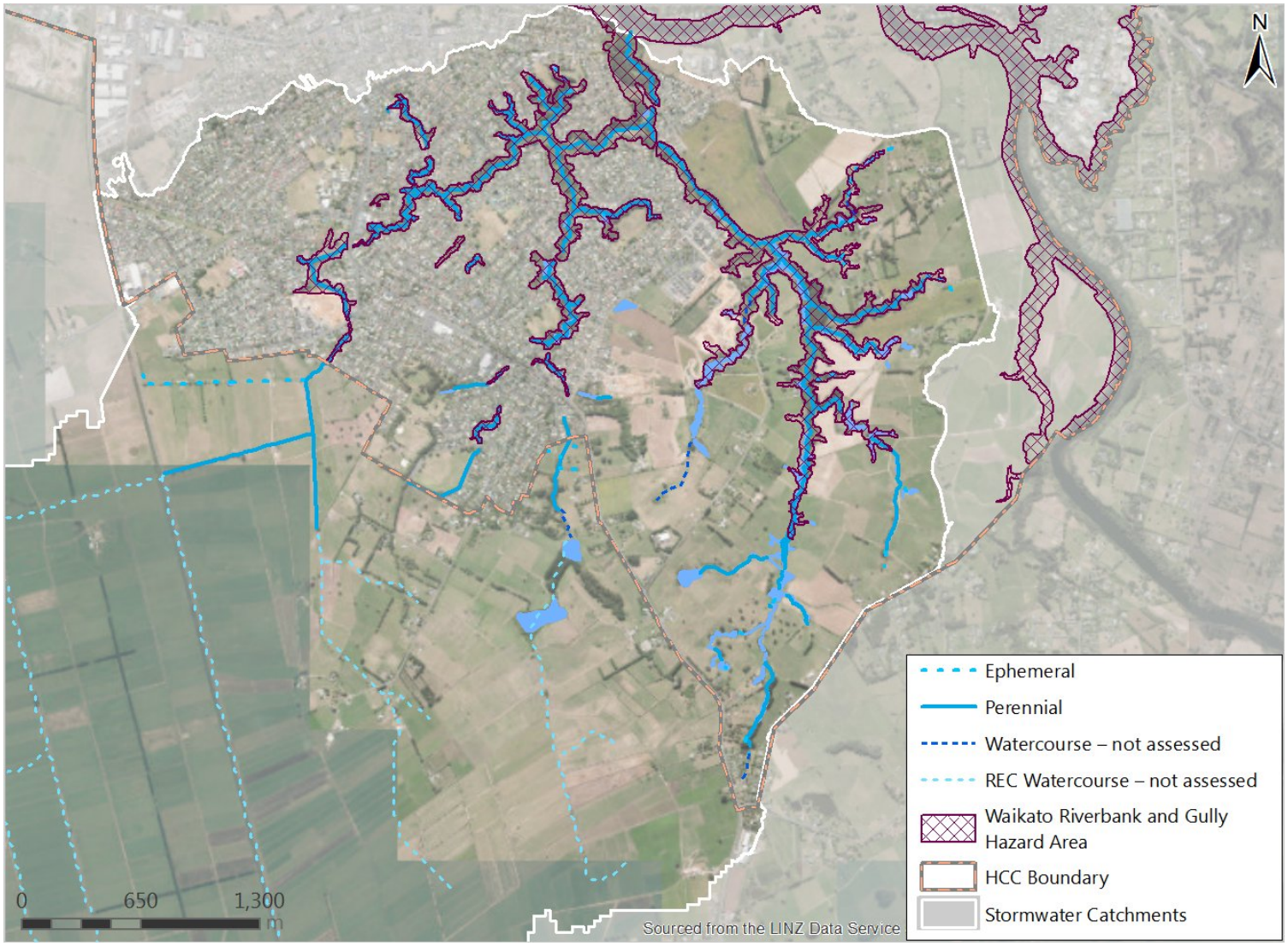


Figure 3: Waikato Riverbank and Gully Hazard Area Mangakōtukutuku.

2.4 Community Involvement and Stewardship

The Mangakōtukutuku Stream Care Group (MSCG) are an active community led group with a vision to improve the ecological values of the stream and increase community awareness supported by the Mangakōtukutuku Puna Koiora Trust.

The MSCG have done a considerable amount of native planting and weeding in the catchment since 2007. Much of the activity to date has been focused along the main channel in the Gully Management Area along Sandford Park and Saxbys Road and includes the installation of a fish passage device (ramp with baffles) to facilitate movement through the culvert at Peacockes Road.

MSCG prepared the Peacockes Riparian Restoration Plan (MSGC, n.d.) which aims to restore native intact riparian vegetation to the main channel and tributaries of the eastern Peacocke sub-catchment. The project targets headwater streams, gully wetlands, and seeps. Planned riparian planting areas in the eastern catchment have been discussed with HCC and the wider Southern Links consortium of consultants. The locations of these proposed planting areas are referenced in the relevant enhancement projects in section 5.3.

2.5 Gully Reserves Management Area

A Hamilton City Gully Reserves Management Plan was initially prepared in 2001 and updated in 2007 (Turner & Craig, 2007). The plan outlines management of six areas of gully which are owned and maintained by HCC and provide some indicative management actions for the portions of gully located on private land.

The main channel of the Mangakōtukutuku watercourse and the lower western sub-catchment (located within Sandford Park) is identified as part of the Gully Reserves Management Plan (totaling 21.3 ha). Priorities and programs for the Mangakōtukutuku Gully are described below:

"Short to medium-term management priorities:

- *Consolidation of existing planting efforts to ensure weeds are controlled and correct balance of species is present.*
- *Progressive restoration of areas currently dominated by exotic forest, shrubs, weeds and vines. A progressive approach is particularly important along the riparian margin where the existing shading provided by exotic trees should only be reduced as native trees achieve significant cover.*
- *Retain existing areas of mown grassland.*
- *Audit culverts, particularly the one under Peacockes Road, to assess suitability for fish passage.*
- *Audit large mature trees to assess threat to gully slope stability.*
- *Introduce shading to streams.*
- *Provide signage to mark way to and from the Waikato River and give information on the values of the gully.*

Long-term priorities for management:

- *Development of picnic and car park facilities.*
- *Progressive replacement of plantations with native vegetation.*
- *Removal of Tradescantia from forest/plantation floor."*

3.0 Methodology

3.1 Receiving Environment Assessment Methodology

The methodology used in the Mangakōtukutuku watercourse assessment is the ICMP Receiving Environment Module developed by Morphum Environmental for Hamilton City Council (HCC, 2015). All interpretation of data should be used in conjunction with this document. The Waikato Regional Council Plan (WRCP) classifications were used to define watercourse types (Table 4) and watercourse classification (Table 5).

Table 4: WRCP watercourse types

Watercourse type	Definition
River	A stream or modified watercourse that does not include any artificial watercourse.
Modified watercourse	An artificial or modified channel that may or may not be on the original watercourse and which has a natural channel at its headwaters.
Farm drainage canal	An artificial watercourse on a farm that contains no natural portions from its confluence with a river or stream to its headwaters and includes a farm drain or a farm canal.

Table 5: WRCP watercourse classification

Watercourse classification	Definition
Perennial	A stream that flows all year round assuming average annual rainfall.
Ephemeral	A stream that flows continuously for at least three months between March and September but does not flow all year.

Several components of the full ICMP Receiving Environment Module were excluded from this survey and are not included in this report as follows:

- Water quality, sediment quality, macroinvertebrate survey and fish survey (undertaken by others).
- A literature review of available information and datasets in the catchment was not undertaken. A literature review was previously undertaken as part of the Draft Mangakōtukutuku Stream Assessment of Ecological Values to inform an ICMP prepared by Boffa Miskell (2014). The report covers the entire hydrological catchment however walkover assessment was limited to portions within the Hamilton City boundary in the central and western sub-catchments only.

3.2 Limitations

3.2.1 Watercourse Classification

The watercourse assessment provides a 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 indicate that a stream is not present or that any such stream is ephemeral. The assessment has been based on the regional plan definitions. It should be noted that these definitions are open to considerable interpretation.

3.2.2 Temporal Variations

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. 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.

3.2.3 Assessment Methodology

It is acknowledged that the ICMP Receiving Environment Module method is a 'rapid' assessment of engineering assets, as well as, biological and geomorphological stream state for the purpose of informing effective management of stream ecology stormwater infrastructure and stormwater conveyance. Therefore, this methodology may lack some parameters of more detailed assessments such as MCI. However, where this information exists it will be considered as appropriate.

4.0 Findings

The watercourse assessment for the Mangakōtukutuku catchment was undertaken in March 2017. This watercourse assessment follows the receiving environment module method (Hamilton City Council, 2015).

This section provides a description of each reach assessed and provides general information on the fish survey results, the wetlands and ponds in the catchment, and the extent of erosion and scouring found.

Stream reaches are divided into 'ecolines' based on significant changes in watercourse morphology, riparian vegetation, land use, or other variables. Each reach was assigned a unique tributary code, refer to Appendix 1 Map 01 for an overview of tributary codes referred to throughout this report.

4.1 Reach Descriptions

The purpose of this section is to provide an overview of the reaches (ecolines) assessed during the survey. Reaches are defined where there are significant changes in riparian cover, channel morphology, erosion and any other parameter considered to change which has an effect on the stream ecology and stream flows. Physical variables of all reaches assessed are summarised in Table 6 below. The Waikato Regional Council Plan classifications are also summarised in Table 6.

The main channel of the Mangakōtukutuku, from the confluence with the Waikato to the confluence with the eastern, central and western sub-catchments is a wide (2 m to 8 m) uniform channel that meanders through Sandford Park.

The western and central sub-catchment main channels are approximately 2 m in width and the steep gullies have good riparian corridors averaging 25 m wide (Figure 4). The corridor is constrained by residential dwellings/buildings located at the top of the gully banks.

Channel modification in the western and central subject catchment includes culverting for road crossings and several areas of bank lining. These remedial works in the form of bank lining would suggest bank failure and erosion has been a historical issue. Additionally, in these bank lining locations, upper bank erosion susceptibility was considered high and there was presence of seepage springs.

Figure 4: Typical reach along central main channel.

In the wider catchment, within Waipa District, the western and central sub-catchment headwaters are a combination of Waipa District maintained drains and modified farm drains. There are areas of community planting and fencing along sections of the watercourse (Figure 5).

Figure 5: Community planting in the Waipa District

The eastern sub-catchment main channel has steep gully banks (15 - 20 m) and a wide confined floodplain typically between 10 - 25 m, with seepage wetlands prevalent along the floodplain and upper banks. The eastern catchment is modified by the presence of several online artificial ponds, predominantly damming headwaters of the main channel and extensively along the length of tributary 2 (MGK_E_Trib2).

Majority of main channel in the eastern sub-catchment has high overhead cover and riparian vegetation within the floodplain. Some areas are heavily impacted by invasive weed species which are threatening regenerating native bush (Figure 6). Majority of the tributaries are located in farm land and are dominated by grazed grasslands or shrub with sparse vegetative cover. Fencing of waterways varies throughout the eastern sub-catchment with areas of stock access and damage more likely in the tributary headwaters where the banks are gently sloping.

Figure 6: **Extensive cover of weed species along gully floor in the eastern sub-catchment.**

Table 6: Summary of physical variables across the extent of watercourse surveyed.

Length of Surveyed Watercourse	25.8 km					
Total No. Ecoline Segments	160					
Average Wetted Width	1.29 m					
Average Depth	0.21 m					
Average Lower Bank Angle	66º					
Average Lower Bank Height	1.25 m					
Average Dominant Substrate	Silt/Sand/Mud					
Waikato Regional Plan Stream Classification		**Permanent**			**Ephemeral**	
length of stream (m) % of total stream length		20,146 (88%)			2,793 (12%)	
Bank Erosion Scarring	**0%**	**≤20%**	**20-40%**	**40-60%**	**≥60%**	
length of stream (m) % of total stream length	801 4%	12,903 56%	7,418 32%	1,603 7%	157 1%	
Overhead Cover	**<10%**	**10-30%**	**30-50%**	**50-70%**	**70-90%**	**<90%**
length of stream (m) % of total stream length	2,097 9%	1,767 8%	3,101 14%	2,853 12%	6,987 31%	6,075 27%

4.1.1 Mangakōtukutuku Main

Lower Mangakōtukutuku (1.2 km) MGK_Main_1-5

The lower Mangakōtukutuku stream is located within Peacockes Esplanade (public reserve) extending from the confluence with the Waikato River (MGK_Main_1) towards Sandford Park (MGK_Main_5).

The lower channel (MGK_Main_1 to 2) has a 7 m wide wetted width and predominantly soft bottomed with varying bank height. The upper true right bank is typically steep dominated by mature pines and exotic vegetation whilst a large floodplain extends from the true left bank with mowed grass and a public walkway. The most significant native vegetation observed included a stand of kahikatea and mahoe seedlings on the left bank likely to be approximately 10 years old. Two erosion hotspots were located on the outside of meanders (both approximately 30 m^2) with high sediment deposition in the lower reaches (Figure 7). There is a channel modification structure at MGK_Main_2 which is providing grade control and dissipation (Figure 8).

Upstream of the culvert at Peacockes Road, the channel (MGK_Main_3 to 5) is fairly uniform with an average channel width of 1 m and 1 m high banks. There is native regeneration planting along the banks (Figure 9.). There are isolated sections of channel modification along MGK_Main_5 which include stacked concrete sacks and placed rocks as bank lining (Figure 10).

Figure 7: Sediment deposition on MGK_Main_2.

Figure 8: Channel/bed modification structure at MGK_Main_2.

Figure 9: Channel MGK_Main_5.

Figure 10: Toe protection at MGK_Main_5.

4.1.2 Central Sub-catchment

Lower Main Channel (1.3 km) MGK_C_Main_1-4, MGK_C_Trib4

The lower reaches of the central sub-catchment extend to the State Highway 3 culvert. The channel ranges in width between 0.8 m and 3 m defined by steep upper banks and good riparian extent (Figure 11). Several large erosion hotspots (approximately 20 m^2) were identified along the true left bank of MGK_C_Main_2 (Figure 12) downstream of Splitt Ave (refer to section 4.4 for more information). Upstream of Splitt Ave there is a considerable planting restoration project around the watercourse and on nearby land likely undertaken by active local residents (Figure 13).

Further upstream in Te Anau Park, there are several seepage wetlands along the floodplains and upper banks (Figure 15). Most of the vegetation is native dominated by tree ferns through the understorey. There are also several bank lining assets along the watercourse in Te Anau Park which consist of stacked tyres or concrete sacks (Figure 16).

There is a small tributary, (MGK_W_Trib4) downstream of the Pelorus Street culvert, which has a deeply incised 100 m section with good overhead cover and sparse bank vegetation providing excellent potential fish habitat (Figure 17). The tributary receives stormwater discharge from a developed area and provides an example of how increases in flow volume and discharge can affect channel stability, in particular where the channel material has poor sheer strength. The observed erosion is likely to be ongoing.

Figure 11: Channel at MGK_C_Main_1.

Figure 12: Erosion hotspot along MGK_C_Main_2.

Figure 13: Restoration effort on the true left bank of MGK_C_Main_3.

Figure 14: Channel along MGK_C_Main_3.

Figure 15: Wetland seepage area on true left bank of MGK_C_Main_4.

Figure 16: Bank lining along MGK_C_Main_4.

Figure 17: Incised and unstable tributary MGK_C_Trib4_1.

Tributary 1 (0.6 km) MGK_C_Trib1

The confluence between tributary 1 and the central main channel is located between MGK_C_Main_1 and 2. Tributary 1 extends east towards Fitzroy Park (Figure 19).

The average channel wetted width is 0.6 m and the average depth is 0.2 m with high upper banks (20 m in the lower reaches and 5 m in the upper reach). There is good riparian extent, diversity, and overhead cover which improves overall bank stability, however, several small active landslips (that did not meet the criteria for erosion hotspots due to small size) were observed which may be caused or exacerbated by seepage and springs located on the mid to upper banks (Figure 18). Near the landslips and along the gully floor there is active sediment deposition (Figure 20), being mainly fine sands and silts. Further upstream the reach is a meandering channel through a low-lying floodplain with extensive cover of tradescantia (Figure 21) which has established on the fine sediments deposits observed throughout. Downstream of the outlet at Waterford Road, there is significant down cutting of the channel which is discussed further in section 4.4.1 (Figure 22).

Figure 18: Landslip on true right bank on MGK_C_Trib1_1.

Figure 19: Channel on MGK_C_Trib1_2.

Figure 20: Sediment deposition within channel on MGK_C_Trib1_1.

Figure 21: Extensive tradescantia cover along MGK_C_Trib1_3.

Figure 22: Active down-cutting and bank slumping of channel along MGK_C_TRIB1_4.

Fork 1 (1.2 km) MGK_C_Fork1

Upstream of Te Anau Park, the main channel of the central sub-catchment diverges. The reach on the right (looking upstream), Fork 1, extends under State Highway 3 and Sunnyhills Ave for 240 m to Dawn Rise with a small tributary located near Lorraine Place (MGK_C_Fork1_Trib1_1).

Downstream of the outlet under the State Highway (MGK_C_Fork1_1), there is a triple culvert with timber lining (above the culvert wingwall) on the upper true left bank (Figure 23 and Figure 24). The bank lining has vegetation growing and rubbish present between the timber planks. The structural integrity of the lining is compromised and the top end is leaning towards the watercourse. The lining is assessed to have a high likelihood of collapsing and maintenance or further assessment is required to remedy this.

Upstream of the inlet to the State highway, there is a 40 m section of timber bank lining (1 m height) on both banks (see Figure 25) along MGK_C_Fork1_1. This lining is likely to restrict flows given the large upstream catchment and there is risk to neighboring properties. Further upstream (a timber bank lining structure has recently been erected on the true left bank approximately 3 m in height (Figure 26).

The watercourse extending towards John Webb Drive is a meandering stream with average bank height 1.5 m and dense tradescantia cover (Figure 27). There are areas of scour and erosion with the most significant area identified as an erosion hotspot just downstream of the John Webb Drive outlet (Figure 28).

Upstream of John Webb Drive (MGK_C_Fork1_3), the channel is a straightened watercourse which flows along the east and south of the Resthills Sports Park (Figure 29). The watercourse has been planted by Mangakōtukutuku Stream Care Group. Upstream of the Resthills Park, beyond the Hamilton City boundary, the watercourse is a network of modified farm drains which is not included in this assessment, as it's outside the subject area.

Figure 23: Bank lining above culvert at MGK_C_Fork1_1.

Figure 24: Bank lining above culvert at MGK_C_Fork1_1.

Figure 25: Bank lining extending 40 m at MGK_C_Fork1_2.

Figure 26: Timber bank lining along property at MGK_C_Fork1_2.

Figure 27: MGK_C_Fork1_2.

Figure 28: Erosion hotspot on MGK_C_Fork1_2.

Figure 29: Channel along Resthills Park MGK_C_Fork1_3.

Fork 2 (1.3 km) MGK_C_Fork2

The reach to the left (looking upstream) of the confluence of the central main channel, fork 2, extends towards Dixon Road, under State Highway 3 and beyond the Hamilton City boundary. The channel downstream of the state highway culvert is an incised with thick tradescantia cover with a large willow lying across the channel and debris build-up evident from previous high flows (Figure 30).

There is a small tributary (MGK_C_Fork2_Trib1_1) that extends under Dixon road which includes a series of weirs along the constructed wetlands identified as the Carbourne Wetlands (Figure 31).

Upstream of the state highway 3 culvert and to the Hamilton City boundary, there is a section of 120 m of weedy uniformly straightened watercourse (MGK_C_Fork2_2) with residential houses in close proximity to the banks. Upstream of the boundary, the watercourse maintains the uniform shape and there is high sediment deposition and some good overhead cover from immediate bank vegetation (Figure 32). The land is un-grazed paddocks with a fenced off channel and several ephemeral tributaries drainage seepage wetlands.

Further upstream along MGK_C_Fork2_4, the channel meanders through a floodplain. There is good riparian cover from pine canopy with weed infestations of blackberry, woolly nightshade and arum lily (Figure 33) in the understorey. The headwaters of the reach are two farm ponds, identified as Alderton A and B which were not assessed as part of this survey.

Figure 30: Willow fallen across incised stream at MGK_C_Fork2_1.

Figure 31: Carbourne Wetland with structure in background.

Figure 32: Fenced off straightened channel MGK_C_Fork2_3.

Figure 33: Floodplain and weedy infestations along MGK_C_Fork2_4.

4.1.3 Western Sub-catchment

Lower Main Channel (1.7 km) MGK_W_Main_1-8

The lower reaches of the western sub-catchment extend from the western/central confluence to MGK_W_Main_8 where the channel morphology changes. The gully banks are typically very steep and >15 m (Figure 34). The bottom of the gully is wide with a large, frequently engaged floodplain narrowing to a more constrained gully with steep immediate banks from MGK_W_Main_4 to 7 (Figure 35). The watercourse channel is fairly uniform, with a consistent width averaging between 2.5 m and 4 m and an average depth of 0.5 m.

There are several natural cascades acting as partial barriers to swimmers with riffles and debris jams providing good habitat complexity and substrate heterogeneity for fish species and macroinvertebrate fauna (Figure 36). Vegetation along this section of watercourse is dominated by tradescantia along the banks with patches of blackberry and a mixed canopy.

Figure 34: Channel along MGK_W_Main_2.

Figure 35: Channel along MGK_W_Main_4.

Figure 36: High velocity and turbulence over natural cascade in bedrock on MGK_W_Main_5.

Lower Tributaries (1.4 km) MGK_W_Trib1-3

There are several tributaries located in the lower reaches of the western sub-catchment downstream of MGK_W_Main_4. The lower reaches of the first tributary (MGK _W_Trib1_1) are defined as a narrow-incised channel with high sediment deposition and high erosion scarring (Figure 42).

Further upstream, the watercourse diverges into two reaches. The reach to the right of the confluence (looking upstream), continues as an incised channel with steep gully banks (Figure 37 and Figure 38). The headwaters received piped discharge from the surrounding residential area and there is a small wetland area immediate downstream of the piped network outlet. The reach downstream of the wetland is likely to be ephemeral (Figure 39).

The reach to the left of the confluence also received piped discharge from the stormwater network. The reach is infested with weeds including tradescantia and blackberry (Figure 40 and Figure 41).

Tradescantia dominates the second tributary covering the entire extent along the upper banks (which are >15 m high) (Figure 43). There is significant bank scarring (40-60% on both banks) along the reach particularly in locations where the channel is highly incised. The tributary receives piped discharge from the stormwater network on either side of Ansford Place.

High gully banks > 20 m define the channel of Tributary 3 resulting in moderate incision and a high percentage of active bank scour affecting upper bank stability (Figure 44). Further information on erosion assessed along this reach is discussed in section 4.4. There are a series of timber weirs along the channel which extend along the banks as timber lining (Figure 45).

Figure 37: Upper bank along MGK_W_Trib1_Fork1_2.

Figure 38: Incised channel on MGK_W_Trib1_Fork1_2.

Figure 39: Wetland at the headwaters of MGK_W_Trib1_Fork1.

Figure 40: Channel along MGK_W_Trib1_Fork2_1.

Figure 41: Channel and floodplain on MGK_W_Trib1_Fork2.

Figure 42: MGK_W_Trib1_1.

Figure 43: Tradescantia cover along MGK_W_Trib2.

Figure 44: Example of channel along MGK_W_Trib3.

Figure 45: Timber weir along MGK_W_Trib3.

Main channel (0.9 km)

The western main channel immediately downstream of the State Highway 3 crossing and upstream towards the Hamilton City boundary (MGK_W_Main_9 to MGK_W_Main_13) has a channel averaging between 2 and 3 m wide wetted width and approximately 0.3 m deep. The upper bank height along these reaches is variable with the lower reaches typical of the steep gullies identified upstream. Further upstream in MGK_W_Main_10 to 12 the bank height decreases to between 1.2 and 2 m high. Recent native riparian planting was identified along both banks of MGK_W_Main_10 which was planted by Mangakōtukutuku Stream Care Group approximately 3-5 years ago (Figure 46).

A new residential development is located on the upper banks of the true left bank around Stan Heather Drive (MGK_W_Main_12). There is an area of exposed loose sediment along the true left bank below the construction site which is pictured in Figure 47 and is recorded as an erosion hotspot, however, it is unlikely this was caused by the watercourse. Local residents have suggested that recent storm events have contributed to tree fall resulting in bank instability and sedimentation. The reach was assessed as fair for the overall bank stability score (Figure 48).

Riparian vegetation along this reach is dominated by exotic species with patches of native tree ferns, however, an infestation of tradescantia dominated both banks from Saxbys Road culvert to the end of MGK_W_Main_13 (Figure 49).

Figure 46: Native planting along MGK_W_Main_10.

Figure 47: Erosion hotspot on true left bank MGK_W_Main_12 (Stan Heather development).

Figure 48: Channel at MGK_W_Main_12.

Figure 49: Upstream of Saxsbys Road at MGK_W_Main_13.

Tributary 5 (0.8 km)

Tributary 5 is a modified perennial watercourse located on the true left bank of the main channel between MGK_W_Main_4 and 5. The tributary has steep gully banks (>20 m high) for majority of the extent with two isolated erosion hotspots on the immediate banks. These are located on the true right bank of MGK_W_Trib5_2 where the bank has recently slumped along the outside meander (see Figure 50) and MGK_W_TRIB5b_1. Most of the channel had good riparian cover dominated by tree ferns (which provide good fish habitat as per Figure 51) however other areas were dominated by thick tradescantia, blackberry and bindweed which limited access to the channel (Figure 52).

In the lower reaches, there are several cascades over bedrock which present barriers to fish passage and are discussed further in section 4.2.

A 70 m long section in the upper reaches of the tributary is lined with concrete as shown in Figure 53.

Figure 50: Erosion hotspot at MGK_W_Trib5_2.

Figure 51: Good fish habitat on MGK_W_Trib5.

Figure 52: Thick tradescantia cover on MGK_W_Trib5_5.

Figure 53: Concrete lined channel on MGK_W_Trib5_7.

Headwaters of Main Channel (2.8 km) MGK_W_Main_14, MGK_Main_Fork1-2

The headwaters of the western sub-catchment are straightened and deepened farm drains which are part of a large network extending well beyond the Hamilton City boundary outside the subject area. The main channel diverges into two reaches after MGK_W_Main_14. Much of the upstream network is impacted by unconsolidated sediment, dark brown peat-stained water and surface sheens and scums. The majority of

these farm drains were fenced with 3 hot-wired fencing and planted with a narrow margin of native riparian vegetation on both banks approximately three years old (Figure 54).

The reach to the right of the diverging confluence includes areas planted and fenced with signage highlighting a community water quality enhancement project, supported by Waikato Regional Council (Figure 55). Further along this reach, the watercourse becomes ephemeral and is extensively culverted for farm crossings by landowners (Figure 56). The reach to the left of the confluence is also planted (Figure 57) and further upstream the channel is dominated by large macrocarpa and blackberry.

Figure 54: Fenced riparian planting on MGK_W_Main_14.

Figure 55: Planting and fencing on MGK_W_FORK1_2.

Figure 56: Channel at MGK_W_Fork1_4.

Figure 57: Native riparian planting on MGK_W_Fork2_2.

4.1.4 Eastern Sub-catchment

Lower main channel (0.7 km) MGK_E_Main_1-3

The eastern sub-catchment confluence with the Mangakōtukutuku main channel is located between MGK_Main_3 and 4. The lower reaches are divided up into three separate ecolines due to significant changes in the channel morphology.

The lower reach (MGK_E_Main_1) extends from the confluence with the main to the Waterford Road culvert. It is a small confined channel with 90-degree banks and steep upper banks approximately 15 m high with residential houses near the top of the banks on the true right bank (identified as a risk and

discussed further in section 5.1.1 and 5.2) (Figure 58). Some sections of the banks are well vegetated (albeit with weed infestations), whereas other areas have bare banks and high mass wasting. A section of the true right bank has had wool matting placed which is deteriorating (Figure 59).

Upstream of the Waterford Road culvert, along MGK_E_Main_2, the watercourse continues as an incised channel with steep gully banks (>20 m) at approximately 60 degrees. The watercourse and upper banks are covered in thick tradescantia, privet and climbers which are smothering native tree ferns and carex grasses (Figure 60).

On MGK_E_Main_3, the channel remains incised with steep gully banks however there is a 15 m wide floodplain on the true left bank with several seepage wetlands and springs (Figure 61). There is mature pine canopy on the true right bank and new developed residential on the upper true left bank.

Figure 58: Incised channel on MGK_E_Main_1.

Figure 59: Wool matting on true right bank of MGK_E_Main_1.

Figure 60: Tradescantia cover of banks and channel at MGK_E_Main_2.

Figure 61: Wetland on floodplain on true left bank of MGK_E_Main_3 and informal walkway in the background.

Main channel (2.1 km) MGK_E_Main_4-11, MGK_E_Trib2_1

The central reaches of the Mangakōtukutuku eastern catchment including MGK_E_Main_4 to 11 and the downstream reaches of the first two tributaries (MGK_E_Trib1 on the true right bank of the main and MGK_E_Trib2 on the true left bank of the main) share similar channel morphology and vegetation. These reaches are characterised as defined gully systems with steep gully banks (>20 m), wide wetland floodplains (20 m) and meandering channels along the gully floor. The most significant factor about these

watercourses are the seepage wetland and springs located along the gully floor and mid to upper banks. These are likely to contribute to baseflow as well as increasing the overall erosion susceptibility of the upper banks.

The vegetation along this section of watercourse differs between understorey of grey willow and areas with weed infestations and carex grasses/rush wetlands. The extensive coverage of weed species from groundcover to emergent trees are interspersed with patches of native vegetation. Exotic smothering type species such as old man beard pose a major threat to regenerating native bush (Figure 64 and Figure 66). The canopy at the confluence of MGK_E_Main_4 and Tributary 1 and 2 is shown on Figure 62.

There are several pools and runs along the watercourse as well as areas of stagnant water with duckweed (Figure 63). Some sections of channels are undercut and scoured; often these areas have sparse ground cover and high overhead cover (shown in Figure 65 and Figure 67).

The land use of the upper banks is rural with areas of fenced farm land and maize production.

Figure 62: Confluence of MGK_E_Main_4 and Tributary 1 and 2.

Figure 63: Stagnant water and willow cover at MGK_E_Main_3.

Figure 64: Floodplain on gully floor of MGK_E_Trib2_1.

Figure 65: Gully floor of MGK_E_Main_7.

Figure 66: Photo take on upper true right bank of MGK_E_Main_10.

Figure 67: Gully floor of MGK_E_Main_10.

Tributary 1 (1.6 km) MGK_E_Trib1_2-9

The first tributary of the eastern Mangakōtukutuku sub-catchment is located on the true right bank between MGK_E_Main_5 and 6. The lower 170 m is described as part of the central sub-catchment above. Further upstream the watercourse transitions to a confined channel and the riparian extent is minimal or absent with overhead cover provided only from the steep upper banks or overhanging grasses. This tributary is shown in Figure 68 (MGK_E_Trib1_2).

Upstream of MGK_E_Trib1_2, the watercourse passes through a 5 m long culvert providing an informal vehicle access. A tributary is located on the true left bank (MGK_E_Trib1a_1) which extends to the southeast. The tributary channel is small and incised with steep upper banks covered in kikuyu (Figure 69). The tributary is spring fed with many small cool pools and water pepper and watercress are prevalent on the immediate banks. The headwaters of the tributary are two ephemeral reaches, the confluence is shown in Figure 70.

The main channel upstream of the 5 m culvert is a small incised channel with steep upper banks approximately 10 m (Figure 71). Exotics grasses provide shading to the watercourse. The watercourse passes through two culverts along this reach. Local residents identified that these are often blocked and cause flooding upstream however; there has been no damage to buildings.

A 100 m section of the watercourse was not surveyed as consent was not provided. Further upstream, along MGK_E_Trib1_8, the watercourse is ephemeral with lower bank height and weed infestations of buttercup and bindweed (Figure 72 and Figure 73).

Figure 68: Transitional reach MGK_E_Trib1_2.

Figure 69: Channel and upper banks of MGK_E_Trib1a_1.

Figure 70: Ephemeral reach at MGK_E_Trib1a_Fork1.

Figure 71: Channel and upper banks at MGK_E_Trib1_4.

Figure 72: Weed infestation across ephemeral channel at MGK_E_Trib1_8.

Figure 73: Ephemeral reach at MGK_E_Trib1_9 taken from road at 20 Peacockes Lane.

Tributary 2 and ponds at 143 Hall Road (1.6 km) MGK_E_Trib2_2-5

The second tributary of the eastern Mangakōtukutuku sub-catchment is located on the true left bank between MGK_E_Main_6 and 7. The lower 200 m and a small tributary (MGK_E_TRIB2a_1) are included in the description of the central sub-catchment above (Eastern Tributary 1). The next upstream section of tributary 2 is a watercourse with a small meandering channel through a buried culvert (MGK_E_Trib2_5) with little understory or canopy cover. There is active sediment deposition and debris along the floodplain as shown in Figure 74 and Figure 75. A 140 m section of the upstream watercourse was not surveyed as consent was not provided.

Upstream of MGK_E_Trib2_5, at 143 Hall Road, 800 m of the watercourse has been extensively modified by the landowner using concrete dam structures to provide a series of eight amenity ponds (Figure 76 to Figure 80). Many of the culvert and dam structures between the ponds were in poor condition.

There is a 400 m reach upstream of the 143 Hall Road property that was not surveyed as access was not permitted. Looking upstream from the boundary of 143 Hall Road, this appears to be a straightened modified channel no riparian cover on the true left (Figure 81).

Figure 74: Buried culvert under farm crossing with wetland floodplain downstream.

Figure 75: Watercourse upstream of the buried culvert MGK_E_Trib2_5.

Figure 76: Downstream pond in series at 143 Hall Road.

Figure 77: Concrete dam structure.

Figure 78: Sixth pond in series at 143 Hall Road.

Figure 79: Bridge crossing and recent earthworks near sixth pond in series at 143 Hall Road.

Figure 80: Eighth pond in series at 143 Hall Road recently constructed.

Figure 81: Looking upstream from 143 Hall Road boundary.

Tributary 3 (0.9 km) MGK_E_Trib3_1-6

The third tributary along the eastern main channel is located on the true right bank between MGK_E_Main_7 and 8. The 200 m lower reach near the confluence (MGK_E_Trib3_1) is a small incised channel with steep upper banks. The channel meanders across the gully floor where the soft sediment is highly erodible and contributes to sedimentation downstream (Figure 82). There is a floodplain on both sides of the channel with sparse ground cover, fern and grey willow understorey and pine canopy on the upper banks.

Further upstream, beyond the pine canopy block, the channel (MGK_E_Trib3_2) meanders across the wide floodplain. There is sparse canopy cover and carex grasses as well as tradescantia, ragwort and blackberry (Figure 83).

The watercourse at MGK_E_Trib3_3 maintains steep upper banks and a wide gully floor. The channel meanders across the floodplain with notable springs on the upper banks. There is good canopy cover from upper bank vegetation as well as willows, tree ferns and tradescantia along the gully floor (Figure 84).

There is an informal farm crossing between MGK_E_Trib3_3 and 4 which currently provides access between two halves of the property. Upstream of the crossing is a large pond (Figure 85) which transitions into a wetland area (Figure 86).

Further upstream the watercourse is likely ephemeral with seepages running along the true right bank. There is a decrease in upper bank height (approximately 10 m). This section of watercourse has wetland species and no canopy and understory (MGK_E_Trib3_5 pictured in Figure 87). A driveway cuts the watercourse at a perpendicular angle with a culvert (Figure 89). Downstream and upstream of the driveway, there is a planted and fenced off area of native and mixed vegetation with upper banks approx. 2 m high (Figure 88).

Figure 82: Incised channel on gully floor on MGK_E_Trib3_1.

Figure 83: Gully Floor on MGK_E_Trib3_2.

Figure 84: Good overhead cover at MGK_E_Trib3_3.

Figure 85: Pond upstream of informal farm crossing MGK_E_Trib3_3.

Figure 86: Upstream of pond at MGK_E_Trib3_4.

Figure 87: wetland reach at MGK_E_Trib3_5.

Figure 88: Ephemeral reach near driveway at MGK_E_Trib3_6.

Figure 89: culvert under driveway of MGK_E_Trib3_6.

Tributary 4 (0.5 km) MGK_E_Trib4_1-2

The fourth tributary on the eastern main channel is located on the true right bank between MGK_E_Main_8 and 9. The tributary has steep upper banks (>20 m) and a wide floodplain gully floor. The channel meanders across the wetland flood plain (see Figure 91). There is significant seepage wetlands located midway on the upper banks. The lower reach (MGK_E_Trib4_1) is shaded by willows growing along the floodplain. The dominant vegetation in upper reaches is carex and exotic grasses (Figure 90).

Upstream of MGK_E_Trib4_2, the watercourse flows through a culvert below an informal farm which is restricting flows resulting in a ponded area upstream. The culvert is in very bad condition with most of the asset already rusted away (Figure 92). There two additional culverted ponds upstream of the driveway (Figure 93).

Figure 90: Wetland floodplain on gully floor at MGK_E_Trib4_1.

Figure 91: Floodplain on gully floor at MGK_E_Trib4_2.

Figure 92: Culvert in poor condition upstream of MGK_E_Trib4_2.

Figure 93: Pond upstream of MGK_E_Trib4_2.

Tributary 6 (1.1 km) MGK_E_Trib6_1-4

The sixth tributary of the eastern sub-catchment is located on the true right bank of the main channel between MGK_E_Main_10 and 11.

The gully at MGK_E_Trib6_1 and the upstream pond have steep upper banks (> 15 m) with a meandering channel along the floor. The gully has had extensive native planting restoration on both banks undertaken by the landowner (Figure 94). There are however; large infestations of weeds present along the gully floor (Figure 95).

Upstream of the pond (which is pictured in Figure 96), there is a healthy rush wetland with gently sloping upper banks (approximately 5 m high) (Figure 97). Further upstream the channel becomes more incised with dense macrophyte cover and high sediment deposition (>1 m) (Figure 98 and Figure 99). These reaches (MGK_E_Trib6_2 to 4) appear to have been straightened along a farm track and are culverted.

Figure 94: Native planting along MGK_E_Trib6_1.

Figure 95: Native planting with weed infestations along MGK_E_Trib6_1.

Figure 96: Pond with native planting upstream of MGK_E_Trib6_1.

Figure 97: Rush wetland along MGK_E_Trib6_2.

Figure 98: Channel along MGK_E_Trib6_2.

Figure 99: Channel along MGK_E_Trib6_4.

Upper channel (1.9 km) MGK_E_Main_12-15, MGK_E_Art_1, MGK_E_Trib7_1-2

Upstream of the defined gully systems, the main channel and tributaries have smaller gully bank heights (<10 m). There are continuous seepages along one or both banks from MGK_E_Main_12 to 15 with high sediment deposition and a mix of run and pools (Figure 100). There is an artificially excavated channel along MGK_E_Main_13 which has been named MGK_E_Art_1 (Figure 101) and a seepage wetland along the true left bank of the artificially channel (Figure 102). It is likely that these channels surcharge and combine as one during high flows. The vegetation along these reaches is grey willow canopy with an understorey of aquatic weeds such as willow weed and alligator weed.

The seventh tributary of the eastern main channel (MGK_E_Trib8) is located on true left bank. The downstream reaches of the tributary are a spring fed rushland with deep pools and high sediment deposition (Figure 103). Further upstream from this rushland, within a deer farm, there is significant pugging and erosion on the banks and channel (Figure 104). The pugged wetland drains a significant sized pond at the top of the tributary (Figure 105).

The eighth tributary of the eastern main channel is located on the true right bank upstream of MGK_E_Main_15. The tributary (MGK_E_Trib8) is a narrow channel which meanders across a wide floodplain with upper banks approximately 3 m high (Figure 106). The tributary is spring feed with seeps located mid-way up the upper banks. There is some pugging and slumping due to the reach being unfenced and large weed infestations (Figure 107).

Figure 100: Channel along MGK_E_Main_12.

Figure 101: MGK_E_Main_13 and MGK_E_Art_1.

Figure 102: Seepage wetland on MGK_E_Art_1.

Figure 103: Pools along MGK_E_Trib7_1.

Figure 104: Pugging of rush wetland with gorse along MGK_E_Trib7_2.

Figure 105: Pond upstream of MGK_E_Trib7_2.

Figure 106: Wetland area with meandering channel on MGK_E_Trib8_1.

Figure 107: Weed infestations along MGK_E_Trib8_1.

Headwater Pond series (0.9 km) MGK_E_Main_15-16

There are a series of culverted ponds along the main channel between MGK_E_Main_15 and 17 (Figure 108 and Figure 109) as well as the entire tenth tributary (MGK_E_Trib10). These ponds have good canopy cover from mature riparian planting and have grasses growing in shallow areas of the ponds. Majority of the ponds are fenced with a 3 hot wire fence making access difficult.

Figure 108: Pond in series at MGK_E_Trib10 .

Figure 109: Culverted pond in upper headwaters of eastern catchment.

Headwaters (0.4 km) MGK_E_Main_17-19

The lower reaches of the eastern sub-catchment headwaters have a wide floodplain and gently sloping upper banks. The channel is well defined along MGK_E_Main_17 where the watercourse has likely been excavated (see Figure 110). Further upstream there is no discernible channel and the floodplain has a dense cover of macrophytes, pasture grasses and carex grasses. The floodplain is entirely fenced with gently sloping upper banks (Figure 111). Upstream of this section the channel has a similar morphology but with dense cover of grey willows and fern undergrowth with patches of weed infestations (Figure 112 and Figure 113).

The upper section of watercourse is likely an ephemeral drain with no defined channel and gently sloping banks. This section was not surveyed as consent was not provided but images are provided from the upstream and downstream end in Figure 114 and Figure 115.

Figure 110: Channel along MGK_E_Main_17.

Figure 111: Wetland floodplain with gently sloping upper banks along MGK_E_Main_19.

Figure 112: Grey willow cover and fern undergrowth along MGK_E_Main_20.

Figure 113: Weed infestations along MGK_E_Main_21.

Figure 114: Looking upstream from MGK_E_Main_21.

Figure 115: Looking downstream from 2131 Ohaupo Road.

4.2 Fish Survey and Barriers

During the survey, there were confirmed sightings of five native fish species (additionally one unidentified galaxiid and unidentified eel) and two exotic fish species. The native fish sightings include:

- Long finned eel (*Anguilla dieffenbachia*)
- Short finned eel (*Anguilla australis*)
- Banded kokopu (*Galaxias fasciatus*)
- Giant kokopu (*Galaxias argenteus*)
- Inanga (Galaxias maculatus)

The summary of fish sightings during the survey is provided in Table 7. It should be noted that the Mangakōtukutuku catchment has previously been identified for its diverse and significant sightings of native fish which also include torrentfish (*Cheimarrichthys fosteri*), banded kokopu, koura (*Paranephrops*), smelt (*Osmeridae*) (Aldridge and Hicks, 2006). There are also historical records of native black mudfish (*Neochanna diversus*).

Restoration efforts by Waikato Regional Council and Mangakōtukutuku Stream care group have included installing several tuna or eel townhouses along the main channel within Sandford Park which are known

to be home to long finned eel and restoring a native wetland upstream of Peacockes Road and introducing black mudfish.

Table 7: Summary of fish observations during assessment within the Mangakōtukutuku catchment.

	Long finned eel	Short finned eel	Unidentified eel	Banded kokopu	Giant kokopu	Unidentified Galaxid	Koi Carp	Mosquito-fish
Main							✓	
Western Sub-catchment								
Lower		✓						
Mid	✓	✓			✓			
Central Sub-catchment								
Lower			✓	✓				
Mid			✓		✓			
Upper		✓		✓				
Eastern Sub-catchment								
Lower	✓			✓		✓		
Mid			✓					
Upper								✓

There were 32 fish barriers identified during the watercourse assessment. These barriers are a result of both anthropogenic (man-made) assets (such as weirs, culverts, aprons) and natural features (such as cascades) and are assessed as partial or complete barriers to fish species based on typical climbing ability: swimmers e.g. inanga, bullies; climbers e.g. banded and giant kokopu, or anguilliformes e.g. eels. It is noted that where a barrier is considered to be a partial barrier to climbers, it is also assumed to be a complete barrier to swimmers.

Overall, there are a small number of existing road crossings in the central and western catchment, this reduces the number of culverts or other structures in the stream channel that may form potential barriers to fish passage. There are also a small number of existing crossings along the main channel in the eastern sub-catchment with the majority of the barriers identified in the headwaters of the tributaries.

Fish passage barriers identified within the catchment have been prioritised for potential mitigation and remediation actions to improve passage over the structure based on the extent and quality of upstream habitat, consideration of nearby fish passages, and proximity to native fish sightings (Table 8).

High priority fish barrier mitigation works include the culvert outlet below Waterford Road in the eastern sub-catchment, a wooden weir structure upstream of Splitt Avenue in the central sub-catchment and an undercut apron below a private driveway in tributary 5 of the western sub-catchment.

The section below provides a commentary on the fish sightings, fish passage barriers, any fish pass structures and areas of good fish habitat within each sub-catchment.

Table 8: Summary of anthropogenic fish barriers identified in the Mangakōtukutuku catchment.

Tributary Code	Barrier Impact	Type of Impact	Priority
MGK_E_MAIN_1	Complete	Swimmers	High
MGK_E_TRIB6_1	Complete	Swimmers	High
MGK_E_TRIB2_6	Partial	Climbers	High
MGK_C_MAIN_3	Complete	Swimmers	High
MGK_W_TRIB5_1	Complete	Climbers	High
MGK_C_FORK1_2	Partial	Climbers	High
MGK_E_TRIB1_5	Partial	Climbers	Medium
MGK_E_TRIB1_4	Partial	Climbers	Medium
MGK_C_TRIB1_2	Complete	Climbers	Medium
MGK_E_TRIB3_3	Complete	Climbers	Medium
MGK_E_TRIB3_3	Complete	Anguilliformes	Medium
MGK_E_TRIB4_2	Complete	Anguilliformes	Medium
MGK_C_FORK2_TRIB1_1	Complete	Climbers	Medium
MGK_C_FORK2_1	Partial	Climbers	Medium
MGK_C_FORK2_TRIB1_1	Partial	Climbers	Medium
MGK_C_FORK2_1	Complete	Swimmers	Medium
MGK_C_TRIB3_1	Partial	Climbers	Low
MGK_W_TRIB3_2	Partial	Climbers	Low
MGK_E_MAIN_17	Partial	Climbers	Low
MGK_E_TRIB3_6	Partial	Climbers	Low

4.2.1 Main Channel

Along the main channel of the Mangakōtukutuku watercourse, near the confluence with the Waikato River (MGK_Main_2), two koi carp were identified near a debris jam (Figure 116).

The Peacockes Road culvert on the main stream was considered to be a barrier to upstream fish passage under most flow conditions (Aldridge & Hicks, 2006). However, the diversity of species previously recorded above this culvert suggests that native species can negotiate this culvert by climbing wetted margins (e.g. eels and banded kokopu) and occasionally by swimming (e.g. inanga and smelt). Species with only moderate climbing ability such as giant kokopu and common bullies also appear to have been able to pass upstream. In 2010, MSCG undertook works on the downstream apron of the Peacockes Road

culvert to improve fish access to upstream habitat for migrating juvenile fish such as giant and banded kokopu (funded by Waikato Catchment Ecological Enhancement Trust and Hamilton City Council).

Figure 116: Debris jam where Koi Carp were sighted along MGK_Main_3.

4.2.2 Western Sub-catchment

In the lower reaches and tributaries of the western catchment, there were sightings of shortfin eel and a sighting of an unidentified eel. There is a natural cascade causing a barrier to swimming species to 400 m of good habitat along tributary 2. Further upstream another cascade is restricting access for swimmers to an additional 50 m. Along the lower reach of tributary 3 near the main channel, a cascade over bedrock is restricting access to swimmers and a timber weir is a partial barrier to climbing species with approximately 70 m of upstream habitat.

In the mid reaches of the western catchment there were several sightings of longfin and unidentified eels and one sighting of a giant kokopu on the lower reaches of tributary 5. Upstream of these sightings (on the main channel and the lower reach of tributary 5) there are several natural barriers to swimming species (Figure 117 and Figure 118) and a barrier to climbers caused by a culvert apron under a driveway (Figure 119). The culvert apron is severely undercut limiting access for most climbing species to approximately 650 m of good potential habitat and is identified as high priority for remediation.

Figure 117: Fish passage barrier to swimming species along MGK_W_Trib2_1.

Figure 118: Fish barrier at MGK_W_Trib5_1.

Figure 119: Culvert under driveway causing a fish barrier at the apron MGK_W_Trib5_1.

4.2.3 Central Sub-catchment

In the lower reaches of the central sub-catchment (the main channel and tributary 1), there were sightings of banded kokopu and an unidentified eel. A fish passage barrier identified along the lower reach of tributary 1 is restricting access for swimming species to 300 m of excellent fish habitat. Upstream a culvert provides a fish passage barrier to climbers and restricts access to an additional 200 m of excellent fish habitat (Figure 120). Tributary 1 provides good spawning habitat for banded kokopu.

Along the main channel (MGK_C_Main_3), a small weir structure is restricting fish passage to swimming species (Figure 121) to at least 1.6 km of good upstream habitat (before additional barriers are encountered). In the mid reaches of the central catchment, climbing species including the giant kokopu (MGK_C_Main_5) and banded kokopu (MGK_W_Trib4) (Figure 122).

Along the first fork in the central sub-catchment, there were sightings of banded kokopu along a small tributary (MGK_C_Fork1_Trib1_1).

The culvert under John Webb Drive (MGK_C_Fork2-3) is slightly perched (less than 100 mm) at the outlet resulting in a fish passage barrier to climbers in low flows pictured in Figure 123. There is good potential habitat above this culvert along the perimeter of Resthills Park. This fish barrier is considered high priority for mitigation.

Along the second fork in the central sub-catchment, MGK_C_Fork2_1, the apron of the culvert outlet which extends under State Highway 3 is restricting swimming species to at least 800 m of satisfactory habitat assuming that there is no network barrier under State Highway 3, however, there the timber weir structure along MGK_C_Main 3 is already restricting swimming species.

Along the small tributary off Fork 2 (MGK_C_Fork2_Trib1_1), the Carbourne wetlands and weir structures present a barrier to climbing species of fish (Figure 124). There is no significant upstream habitat upstream of the Carbourne Wetlands under the current development flows.

Figure 120: Perched culvert presenting a fish barrier in low flows.

Figure 121: Weir structure upstream of Splitt Ave along MGK_C_Main_3.

Figure 122: Banded kokopu caught on MGK_C_Trib4_1.

Figure 123: Fish barrier under John Webb Drive.

Figure 124: Carbourne Wetlands fish barrier.

4.2.4 Eastern Sub-catchment

In the lower reaches of the eastern sub-catchment on MGK_E_Main_1 and 2, a number of unidentified galaxid were spotted in the scoured pool below Waterford Road outlet (Figure 125). The scoured pool is good habitat for fish with overhead cover from canopy and a substantial amount of debris in the pool. The culvert apron is causing a fish barrier with a drop of 0.1 m to water surface and 0.4 m to the channel bed.

MGK_E_Main_3 provides excellent fish habitat with undercut banks, overhanging vegetation, and large woody debris. During the walkover survey, there were sightings of banded kokopu and longfin eel.

The defined gully system along the main channel provides excellent habitat for fish with several deep pools, large woody debris and areas of undercut banks (Figure 126). Shortfin eel were the only species identified along these reaches however there were sightings of banded kokopu and longfin eel in the lower reaches of the tributaries upstream (MGK_E_Trib3_3 and MGK_E_Trib4_1).

There are two fish passage barriers along tributary one of the eastern sub-catchment. These culverts present partial barriers to climbing species due to their drop height on the outlet. Much of the upstream habitat is likely to be ephemeral.

Culvert damming of ponds upstream of MGK_E_Trib2_6 has been undertaken over 950 m of stream. The dams have formed several barriers to fish passage. The most downstream concrete earth dam structure presents a barrier to anguilliforms. Further fish passage barriers were not assessed during the assessment of ponds and culverts upstream of here.

Along tributary three, there is good habitat for fish with a mix of runs riffles and pools with large amount of debris and some bank undercut. During the survey, there were sightings of banded kokopu and longfin eel in the channel. A twin culvert below the informal crossing between MGK_E_Trib3_3 and 4 presents a fish passage barrier to climbing species (Figure 127). There is good upstream habitat along MGK_E_Trib3_4.

Along tributary 4, a poor condition culvert upstream of MGK_E_Trib 4_2 presents a complete barrier to all fish species (Figure 92). There is good upstream habitat for fish including a large pond and wetland.

Along tributary 6, the channel has large pools and riffles and provides excellent habitat for fish. During survey banded kokopu and longfin eel were identified along the lower reaches of this tributary. There is a fish passage barrier downstream of the large pond along the tributary which looks to be fitted with a spat rope (Figure 128).

In the headwaters of the eastern catchment the culverted ponds along MGK_E_Main_15 and 17 and MGK_E_Trib10 have high abundance of the invasive mosquito fish. A full assessment of culverts along these ponds was not undertaken due to the 3 hot-wired fencing.

Figure 125: Outlet of Waterford Road culvert.

Figure 126: Defined gully floor providing good fish habitat.

Figure 127: Fish barrier at perched culvert under farm crossing upstream of MGK_E_Trib3_3.

Figure 128: Spat rope fitted at culvert upstream of MGK_E_Trib6_1.

4.3 Wetlands/Ponds

Ninety-one wetlands or ponds have been recorded in the Mangakōtukutuku catchment which farm ponds, aesthetic ponds and culverting damming as well as seepage springs fed natural wetlands (Figure 129).

The most common types of artificial ponds observed in the catchment were culverted ponds with a significant chain of ponds at 144 Hall Road and the headwaters of the eastern sub-catchment.

The most common type of natural wetlands observed in the catchment was seepage wetlands along gully floors and upper banks. Springs and seepages contribute to the baseflows of the watercourses and can alter the stability of upper banks. This is discussed further in section 4.4.2.

Much of the gully floor along the eastern catchment is a wide floodplain with a meandering channel and is classed as a riverine wetland. Dominant vegetation includes substantial areas of willows and carex, rush wetland species. The riverine wetland and seepage wetlands, although impacted by invasive weeds and stock access, provide important habitat and ecosystem service functions, such as, habitat for macroinvertebrates and avian wildlife, and water quality and quantity functions. The gully floors provide excellent spawning habitat for fish species such as banded kokopu.

All wetlands also provide some level of ecological value including provision of habitat for aquatic macroinvertebrates, fish, and/or water fowl. However, online farm ponds and aesthetic ponds also contribute to negative environmental impacts such as: potential barriers to fish passage; reduced low dissolved oxygen levels; thermal stratification and discharge of higher temperature water.

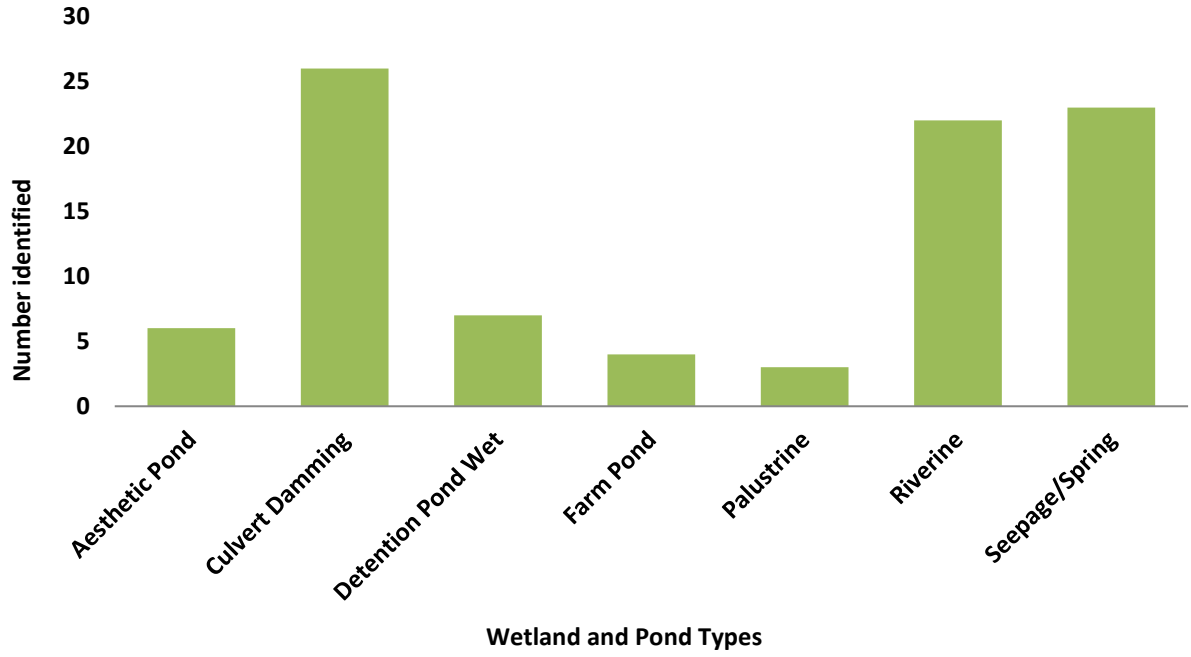


Figure 129: Number of wetlands and ponds identified in the Mangakōtukutuku catchment.

4.4 Erosion and Scour

Streams naturally erode and change course over time. Overall, the presence of erosion scarring along the banks of the Mangakōtukutuku catchment is generally low with <20% bank scarring along banks considered typical of a natural watercourse. Much of the bank erosion scarring is located along small contributing reaches leading from the stormwater network to the main channels as well as isolated sections along the main channels. Upper bank stability scores range between 'good' to 'poor' with no reaches returning an 'excellent' score.

4.4.1 Erosion Scarring and Erosion Hotspots

Erosion scarring of the reach is assessed as a percentage of the total length of each reach for each bank separately. Erosion scarring is assessed as the area of exposed earth (or recently exposed with some herbaceous vegetation cover) on the stream bank that resulted from bank slumping or scour.

Erosion hotspots are identified as discrete locations of severe erosion causing environmental, infrastructure, and/or health and safety risk. An erosion hotspot is defined as severe erosion located within the channel and or, lower or upper banks, resulting in slumping and exposed soil surfaces and must be;

- actively eroding,
- exceed 2 m in length or have a total surface area of >5 m^2,
- be detrimental to stream health or causing significant and/or immediate safety or infrastructure concerns.

Two assessment criteria provide the overall risk value of the erosion hotspot; instability score (3 or 4) and asset risk score (1 to 4). Overall, if the sum of stability score and asset score is great than 6, the hotspot is considered high risk.

Locations of bank scarring >60% and 40-60%, bank lining assets and high/medium risk erosion hotspots are discussed below for each sub-catchment.

4.4.2 Main Channel

Along the main channel, near the Waikato River confluence, there are two erosion hotspots which present a significant area of bank slumping and scour along the true left bank. These areas are within close proximity to the public access track which exists on the upper bank and were therefore assessed as high risk (asset risk score of 3 and erosion score of 3). One of the erosion hotpots is shown in Figure 130.

Further upstream along MGK_Main_4 and 5, there is erosion scarring along 20 – 40% of the banks. This reach also has some bank lining assets which consist of toe protection as shown in section 4.1.1. Recent planting and regrading along the reach has been undertaken by the Mangakōtukutuku Stream Care Group (designed by T&T) in an effort to manage erosion (among other objectives) along this reach (Quilter & Miller 2014).

Figure 130: Erosion Hotspot along MGK_Main_2.

4.4.3 Central Sub-catchment

There are several areas of saturated banks causing erosion hotspots along the central main channel. These generally correspond with areas where seepage locations have also been identified on upper banks. An example of this is along the reaches MGK_C_Main_4 and 5 shown in Figure 131.

Bank erosion scarring at MGK_C_Trib1_2-4 was observed to be 40-60% along both banks (Figure 132). There were several areas of bank slumping and vegetation falling across the channel. In the upper reach, MGK_C_Trib1_4 the channel is actively down-cutting and undercutting banks and there is extensive sediment deposition.

During a follow up walkover of selected reaches in June, an erosion hotspot was identified along MGK_C_Trib1_2 where slumping along the true left bank resulted in a ponga tree and debris to fall across the channel. The erosion score was assessed as 4, however, the asset risk score was 1 therefore the overall risk score is medium. Scouring was evident along this area and there was high sedimentation downstream (Figure 133).

MGK_C_Trib2_1 is 35 m long and with a highly incised channel, steep upper banks (10 m) and high bank erosion scarring (> 60% on both banks) (Figure 134). There are debris jams along the 35 m reach with

areas of thick tradescantia. The reach receives discharge from the piped network via a 600 mm culvert. The outlet has corrugated iron and rocks as a dissipating structure however there is evidence of powerful flows along this reach.

The fourth tributary of the central main channel (MGK_C_Trib4) is a highly incised 100 m reach which is assessed as >60% erosion scarring on both banks (Figure 135). The reach receives pipe discharge from the stormwater network through a 425 mm pipe. The immediate banks along the reach are vertical or near vertical and approximately 2.5 m high. The gully banks are steep with an overall stability score of poor. There is extensive planting along the reach with native understory and good overhead cover however; the reach has poor density of vegetation and root mass.

Figure 131: Erosion hotspot on MGK_C_Main_4.

Figure 132: Down-cutting along MGK_C_Trib1_4.

Figure 133: Bank slumping and scour along MGK_C_Trib1_2 assessed during June 2017 walkover.

Figure 134: Erosion and scour along MGK_C_Trib2.

Figure 135: Incised reach at MGK_C_Trib4.

4.4.4 Western sub-catchment

The first tributary of the western channel (MGK_W_Trib1) is assessed as having 40-60% erosion scarring along both banks and high sediment deposition was observed. The headwaters of the tributary are two reaches which receive discharge from the stormwater network via several outlets near Bader Street and Pine Avenue.

The reach to the right of the confluence (looking upstream) is a deeply incised channel with active down-cutting and bank undercutting along the channel (Figure 136 and Figure 137). The reach has steep upper banks with pine canopy and little understory or ground cover to provide bank stability.

The reach to the left of the confluence (looking upstream) is a small watercourse with reaches alternating between incised channel to shallow meandering channel (Figure 138). The reach has steep upper banks dominated by weeds including tradescantia.

Further downstream, the channel widens but maintains high erosion scarring along banks with several minor bank slumps and soft erodible soil. Where the tributary meets the main western sub-catchment channel, there is an erosion hotspot with an overall risk value of medium which identified undercutting of the bank. During the June 2017 walkover, the bank had failed and a ponga tree and debris had fallen into the channel.

An isolated section (25 m) of the third tributary along the western main channel (MGK_W_Trib3_1) has >60% bank erosion on both banks. The section of stream is incised with steep gully banks >20 m and evidence of high flows from the amount of debris deposited on the upper banks (Figure 139). There was high sediment deposition with little to no flow during survey. There is limited vegetation on the immediate banks however there was good cover from the surrounding canopy. Upstream, a series of wooden weirs and bank lining structures were observed which may contribute to the erosion identified further downstream (see Figure 140).

Figure 136: Incised channel and erosion scarring along MGK_W_Trib1_Fork1_2.

Figure 137: Bank undercutting along MGK_W_Trib1_Fork1_1.

Figure 138: Incised channel along MGK_W_Trib1_Fork2.

Figure 139: High erosion reach along MGK_W_Trib3_1.

Figure 140: Wooden weir structures upstream of high erosion reach MGK_W_Trib3_1.

4.4.5 Eastern Sub-catchment

Overall, the eastern sub-catchment had fair to good stability scores with erosion scarring typically below 40%.

There is one location identified as an erosion hotspot where there is active down-cutting of the channel bed, and slumping of the immediate banks. The banks are highly erodible and often saturated indicating the presence of seepages or springs along the floodplain. The erosion hotspot has an overall risk of medium as there is no risk to public infrastructure or assets (Figure 141). However, given the location of this erosion hotspot within Greenfield land, appropriate management of stormwater inputs should be

sought as per Management Zone 1 (section 5.1.1). The reach has good cover from pine forest and mixed native and exotic understory.

Figure 141: Erosion hotspot along MGK_E_Trib3_1.

4.4.6 Upper Bank Erosion Susceptibility

Upper bank erosion susceptibility is assessed using the Ecoline feature per reach. The assessment uses the Upper Bank stability assessment as per Pfankuch (1975). The upper banks are defined as the *"portion of the topographic cross section from the break in the general slope of the surrounding land to the normal high-water line. Terrestrial plants and animals normally inhabit this area"*.

Each assessment reach of the Mangakōtukutuku Watercourse was assessed for land slope, mass wasting, debris jam and bank vegetation and given a score of Excellent, Good, Fair or Poor. These each correspond with a number and a final score is calculated as the overall stability score (Table 9-12).

The overall upper bank stability in the Mangakōtukutuku varies between poor and good with no reaches returning an excellent score. Areas with poor upper bank stability are located;

- within the central sub-catchment along the main channel (MGK_C_Main_2) (Figure 142),
- the first tributary in the central sub-catchment (MGK_C_Trib1),
- the first fork along the first tributary in the western sub-catchment (MGK_W_Trib1_Fork1) and,
- the small (<100 m in length) tributaries in the central catchment (MGK_C_Trib2 to MGK_C_Trib4) also have poor upper bank stability (Figure 143).

These areas also correspond with areas of active erosion as discussed in section 4.4.1.

The main channel upstream of the confluence with the Waikato River, the main reaches of the eastern catchment, selected areas of the western sub-catchment and the remaining middle and lower reaches of the central catchment have an overall stability score of fair. For the majority of these reaches, land slope of the upper banks are assessed as poor as the gully banks are steep and between 10 and 25 m high. An example of the upper bank height in the eastern catchment is given in Figure 144.

Of particular concern are the observed upper bank stability scores of poor and fair along the main channel of the eastern sub-catchment. The height (20 m) and angle (above 50 degrees) of the gully banks considered with the presence of seepages and springs along the banks present a real hazard for future

development. The saturated nature of the soil along the banks increases the mobility of the bank material and the likelihood of mass slumping and undercutting.

Table 9: Summary of Pfankuch bank stability assessment of the main channel (% of total stream length).

	Excellent	Good	Fair	Poor
Land Slope	0	0	48%	52%
Mass Wasting	0	0	93%	7%
Debris Jam	0	52%	48%	0
Bank Vegetation	0	100%	0	0
Overall Stability Index	0	0	100%	0

Table 10: Summary of Pfankuch bank stability assessment of the central sub-catchment (% of total stream length).

	Excellent	Good	Fair	Poor
Land Slope	11%	34%	33%	22%
Mass Wasting	0	61%	30%	9%
Debris Jam	0	74%	9%	16%
Bank Vegetation	0	73%	18%	9%
Overall Stability Index	0	56%	40%	4%

Table 11: Summary of Pfankuch bank stability assessment of the western sub-catchment (% of total stream length).

	Excellent	Good	Fair	Poor
Land Slope	27%	7%	7%	60%
Mass Wasting	12%	17%	27%	44%
Debris Jam	5%	36%	33%	26%
Bank Vegetation	0	40%	54%	6%
Overall Stability Index	0	27%	50%	22%

Table 12: Summary of Pfankuch bank stability assessment of the eastern sub-catchment (% of total stream length).

	Excellent	Good	Fair	Poor
Land Slope	11%	50%	18%	22%
Mass Wasting	8%	64%	20%	7%
Debris Jam	12%	47%	32%	8%
Bank Vegetation	0	40%	33%	27%
Overall Stability Index	0	37%	59%	4%

Figure 142: MGK_C_Main_2 assessed as poor land slope, poor mass wasting, poor debris jam and good vegetation. Overall stability score is poor.

Figure 143: MGK_C_Trib3_1 assessed as poor land slope, poor mass wasting, fair debris jam, and fair bank vegetation. Overall stability score is poor.

Figure 144: Confluence of eastern sub-catchment main channel and tributary.

5.0 Options and Actions

5.1 Management Zones

Management Zones (MZ) are spatially defined areas based on similar land use pressures, environmental values and geographic/network context. Options for erosion mitigation, enhancement and management have been outlined for these areas. It is anticipated that these management zones will form the basis of management actions to be considered in the Mangakōtukutuku ICMP, which is under development at the time of writing.

Six overarching management zones have been defined and mapped for the 26 km of watercourse surveyed in the Mangakōtukutuku catchment (Figure 145) and summarised in Table 13. These are described following and include:

1. Eastern Main Channel and Wetlands (MZ1)
2. Eastern Modified Tributaries (MZ2)
3. Western and Central Tributaries (MZ3)
4. Western and Central Main Channels (MZ4)
5. Western and Central Farm Drains (MZ5)
6. Eastern Tributaries and Wetlands (MZ6)

For each of the MZ's outcomes have been defined to support management actions. Outcomes are generally grouped in the following manner:

- Terrestrial ecological outcomes
- Freshwater ecological outcomes
- Stormwater outcomes

For the western and central sub-catchments some of the existing common pressures and impacts result from historical and existing land use including:

- Loss of riparian margin vegetation;
- Stock access to waterways;
- Contaminants entering waterways; and,
- Barriers to fish passage

Management zones 3, 4 and 5 are located within the central and western sub-catchment, as the Brownfields watercourses and headwaters. The pressures and impacts on the watercourse in the central and western sub-catchment are identified and considered as part of this report. The opportunities identified are both consenting requirements (fish passage barrier mitigation as part of the CSDC), conveyance of stormwater and increasing the biodiversity value of reaches. This may include providing support to community groups for weeding and planting (such as those identified by the Mangakōtukutuku Stream Care Group).

Management zones 1, 2 and 6 are located within the eastern sub-catchment. The pressures and impacts of growth on the eastern Peacocke sub-catchment are of particular importance with the changing land use where there is opportunity and consenting requirements to enhance part of the network. The main pressures and impacts identified in the eastern sub-catchment as a result of recent and proposed Greenfield development include:

- Change in land use and the associated contaminants of concern;
- Increased imperviousness and associated changes in hydrograph and impacts on watercourses, including increased potential for channel erosion and reduced base flows; and,

- Further potential barriers to fish passage with the development of more roads and associated culvert structures.
- Loss of riparian connectivity through the main gully channel.

Guiding objectives for the management of the catchment are:

Terrestrial Ecological:

- Protection and enhancement of areas of significant habitat incorporating buffers to protect sensitive habitats, weed control, and facilitate natural regeneration processes;
- Encourage diversity in motorway plantings to increase the habitat potential of these large areas of restoration plantings;
- Encourage use of native tree species plantings (e.g. street trees) to connect with riparian networks.

Freshwater Ecological:

- Protection of natural drainage through the catchment;
- Provide riparian margins through development setbacks;
- Provide for recreational and amenity values through protection of watercourses;
- Enhancement of streams and wetlands, especially those with no riparian vegetation;
- Removal of exotic riparian species (in stages if required), and replace with native species;
- Mitigation of barriers to fish passage, through removal/upgrading/retrofitting of culverts.

Stormwater Outcomes

- At source (or as close as possible) stormwater management methods are preferred to mimic natural hydrology. Where specific site constraints require centralised devices their proposed efficiency should be considered;
- Encouraging developers to consider a water sensitive design process;
- Treatment of high contaminant generating areas.

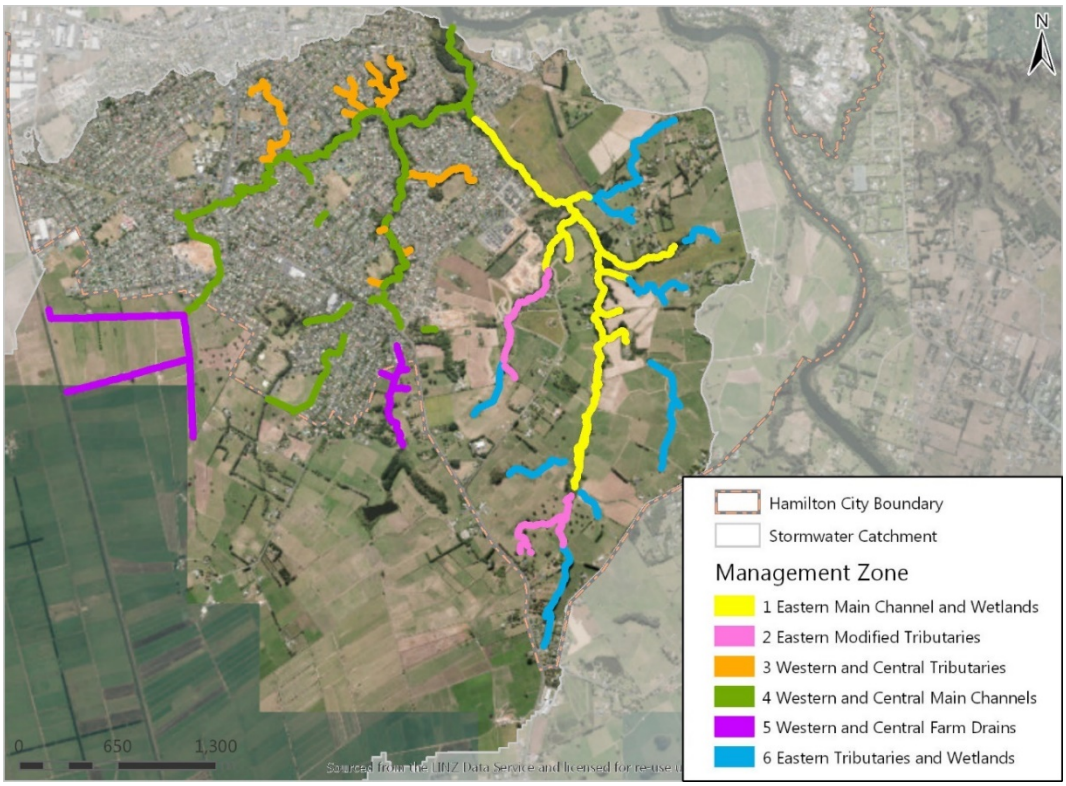


Figure 145: Mangakōtukutuku Management Zones.

5.1.1 Management Zone 1 – Eastern Main Channel and Wetlands

The undeveloped eastern sub-catchment has steep upper banks and a wide floodplain gully floor forming riverine wetlands dominated by rushes and sedges. The main channel through these wetlands is sinuous. Riparian vegetation is variable ranging from areas dominated by grey willow, mature pines, or minimal canopy and dominated by weed infestations including tradescantia and blackberry. High sediment deposition was commonly observed in reaches dominated by mature pines. The upper bank stability scores along these reaches are generally poor or fair.

There is wetland seepage located along the upper banks or along the floodplain areas in several locations. These seepage springs cause the ground to be saturated (increasing erosion susceptibility) and are considered a highly sensitive environment for both hydrology and biodiversity reasons.

Through the development process of the eastern sub-catchment, the main channel watercourse is likely to experience increased volumes of stormwater runoff (and if not attenuated then also increased peak flows). The Mangakōtukutuku gully is likely to have enough capacity to deal with large volumes given the width and depth of the channel however this would be at a cost to the stability of the banks as the majority of these reaches are assessed as fair bank stability. Currently, erosion scaring was observed over less than 40% of reaches. Increased flows and volumes are likely to increase scour of gully floor and fluvial erosion of the lower stream banks resulting in undercutting of banks and stream widening. The presence of seepages and springs further reduces the overall bank stability and may result in a higher risk of bank failure.

Following development, erosion is expected to increase due to increased flow volume and the potential for increased peak flow velocities. This will result in downcutting and widening of the stream, an increase in sediment loss and the potential loss of ecological value if wetland engagement reduces. The effects of erosion will worsen over time, and is anticipated to require remediation works in approximately 5 to 10 years from the time of development.

As part of the management of these reaches and the overall development strategy of the Peacockes structure plan implementation, an adequate set back of infrastructure should be identified from the top of the banks. This should be supported by a hydrogeology and geotechnical investigation.

The riverine wetland and seepage wetlands, although impacted by invasive weeds and stock access, provide important habitat and ecosystem service functions, such as, habitat for macroinvertebrates and avian wildlife, and water quality and quantity functions. The gully floors provide excellent spawning habitat for fish species such as banded kokopu. Several banded kokopu and longfin eel were sighted throughout or upstream of this management zone.

Maintaining baseflow is important to protect and sustain the riverine wetland and seepage wetland ecology. This should be further investigated through the hydrogeology investigation.

Structures forming a barrier or restricting fish access throughout the gully area should be considered for removal or mitigation. These include the twin culverts beneath a farm crossing along MGK_E_Trib3_3 (ID 009 and 010) and outlet below a driveway crossing at MGK_E_Trib6_1 (ID 012).

Planting works should be prioritised for the areas within Hamilton City Council owned land and considered for community engagement or public purchase for the privately-owned areas.

Much of the land is predominantly privately owned however; as part of the Southern links designation, several properties corresponding with this management zone will be acquired by council. Council may be in a position to acquire land that is deemed suitable for the Ecological Monitoring and Management Plan restoration locations during Greenfields development.

Suggested actions and objectives specific to Management Zone One are to:

1. Plant native riverine wetland species along the gully floor and appropriate native riparian buffer on banks prior to staged willow removal through appropriate Waikato Regional Council practice;
2. Increase channel heterogeneity and provision of toe protection through introduction of sand/pebbles/cobbles to the channel bed in locations where existing erosion is <20% and bank stability is fair or poor;
3. Mitigation of fish barriers and consideration of upgrade or removal of culverts;
4. Promote the reduction of stormwater flows through incorporation of on lot water quality detention devices and centralised sub-catchment devices prior to the consideration of mitigation measures;
5. During development, manage location and number of stormwater outlets to MZ 1 watercourses to allow for appropriate outlet structure design;
6. Promote the protection of upper bank and gully bank vegetation to reduce the likelihood of bank vegetation removal during construction and development applications in line with action 1.

5.1.2 Management Zone 2 – Eastern Modified Tributaries

There is extensive modification of the watercourse in the eastern sub-catchment tributaries which include damming the watercourse to make a chain series of online ponds.

Online ponds and culvert damming cause surface water to pool and back up behind culverts. As a result, baseflows are often reduced especially during summer with impacts on water quality and freshwater ecology including increased temperatures and lowering of dissolved oxygen levels. Online ponds also present preferred habitat for exotic pest species such as mosquito fish.

Series of online aesthetic ponds are located in two discrete locations of the eastern sub-catchment in Mangakōtukutuku. These locations are: the midsection of Tributary 2 at 143 Hall Road (900 m of watercourse dammed to make a chain of eight ponds); and a section of the headwaters of catchment (300 m of watercourse dammed to make a chain of seven ponds) and the nearby tributary 10 (310 m of watercourse dammed to make a chain of 10 ponds).

The removal of online ponds in the catchment is generally recommended however the decision to remove, enhance or modify the ponds will depend on several constraints and opportunities including:

1. The cost of (and appetite for council to pay) for the naturalisation of the channel to return to natural state and the future ownership of the land (council vs privately owned);
2. The requirement/need for the ponds to become centralised sub-catchment stormwater management devices if the surrounding typography and location within the catchment is suitable;
3. The likelihood or authorisation of the dam/culverting works and structure to become consented under the RMA 1991;
4. The availability of upstream habitat for native fish species;
5. The existing function of the pond to restrict flows and provide detention to reduce downstream erosion and scour.

5.1.3 Management Zone 3 –Western and Central Tributaries – Erosion Remediation

The reaches under MZ3 include the tributaries to the main channel of the western and central sub-catchments. These areas generally require the most in stream works and should be prioritised as erosion mitigation projects. Refer to specific projects in section 5.2 and 5.3 for further details.

Several of the tributaries draining to the main sub-catchment channels have high erosion scarring with undercut banks. These reaches receive flows from the stormwater network via several outlet structures. Overhead cover is variable with good shading and riparian extent coinciding with reserves such as Te Anau Park, Fitzroy Park and Sandford Park.

There areas are considered to have good fish habitat and present an opportunity for increased ecological value with fish passage mitigation while maintaining aspects of existing channel morphology. The highest priority fish barrier mitigation in this management zone is the undercut culvert beneath a private drive crossing along MGK_W_Trib5_1 (ID 027). It is recommended that council consider the following mitigation measures under this management zone:

1. Re-grading of banks to 3:1 (maximum) slope;
2. Provide toe protection to reduce down-cutting in stream while increasing channel heterogeneity for fish habitat and introduction of woody debris, log overhangs and refuge tunnels;
3. Mitigation or removal of high priority fish barriers during works;
4. Weeding on immediate banks particularly tradescantia infestations and plant species with deep root mass along the banks;
5. Maintain overhead cover.

5.1.4 Management Zone 4 – Western and Central Main Channels – Biodiversity and Conveyance

Majority of the western and central main channels in the Mangakōtukutuku catchment are stable, uniform channels with approximately 1 m wide wetted width and steep upper banks. These reaches have an important conveyance value to provide the pathway for stormwater in the catchment to the Waikato River.

These reaches generally have high watercourse shading and low bank erosion scarring. The vegetation along the reaches are predominantly exotic with significant infestations of tradescantia. Isolated sections have been planted and maintained by the Mangakōtukutuku Stream Care Group supported by Hamilton City Council and Waikato Regional Council.

It is recommended that HCC supports and contributes to community plantings organised by Mangakōtukutuku Stream Care Group in these areas and considers projects along the reaches to restore the riparian extent to native.

HCC must also recognise the importance of these reaches for stormwater conveyance and therefore maintenance of assets along these sections must be managed. Maintenance measures include:

1. Repair or replace bank lining assets identified to be in poor condition;
2. Mitigate existing erosion hotspots by regrading banks, providing toe protection, or consider artificial bank lining;
3. Repair or replace culverts identified to be in poor condition (e.g. condition rating of 4 or 5);
4. Mitigation or removal of fish barriers.

5.1.5 Management Zone 5 – Western and Central Farm Drains

The headwaters of the western and central sub-catchments are agricultural farm drains. These reaches have been straightened and, in some cases, deepened to lower the water table and provide additional arable land. These areas are likely to have historically been part of a peatland wetland. It should be noted that both the western and central headwaters extend beyond the subject catchment and it is assumed that the drains are similar in morphology and the management can be applied to the entire drainage network.

A small proportion of these watercourses were accessible to stock, this is likely due to the fact that the Mangakōtukutuku Stream Care group and Waikato Regional Council have been active in planting and fencing especially in the western catchment. The farm drains are located on privately owned land.

Suggested actions and objectives specific to this Management Zone are to:

1. Support the Mangakōtukutuku Stream Care Group in the engagement with landowners to:

a. Plant all stream banks with native riparian vegetation to a width of 20 m on both banks where possible (with consideration of conveyance functions and flood flows);
b. Promote stock exclusion via fencing to protect watercourses, natural wetlands and springs;

2. Investigate for possible mudfish habitat.

5.1.6 Management Zone 6 – Eastern Tributaries and Wetlands

The headwaters of the tributaries and main reaches of the eastern sub-catchment in the Mangakōtukutuku catchment are low lying wide floodplain reaches or seepage wetlands often fed by springs. Majority of these areas have little overhead cover from vegetation, sparse understorey and are more than likely grazed by stock.

All of the watercourse in this management zone will be affected by Greenfield development. The reaches are expected to experience increased volumes and stormwater runoff, and if not attenuated, also increase peak flows. Currently erosion scaring is generally less than 20%. Following development, erosion is expected to increase with the stream channel becoming more defined, resulting in downcutting. It is anticipated that erosion remediation works may be required approximately 10 to 20 years following development.

The surrounding land is predominantly privately owned, however, as part of the Southern links designation, several properties corresponding with this management zone will be acquired by council. Council will also endeavour to acquire land that is deemed suitable for the Ecological Monitoring and Management Plan restoration locations during Greenfields development. *Suggested actions and objectives specific to this Management Zone are to:*

1. Plant native riverine wetland species along the floodplain floor and native riparian buffer while undertaking tradescantia, gorse and blackberry removal;
2. Identify set back of developable land based on the Waikato Riverbank and Gully Hazard Area and presence of seepage wetlands and springs;
3. Mitigation or removal of fish barriers;
4. Provide for recreational and amenity values through protection of watercourses;
5. Consider stormwater treatment and management devices in the headwaters of tributaries.

5.1.7 Management Zone Summary

Table 13: Summary of Management Zones

	Management Zone	Land Development type	Description	Main issues	Opportunities
MZ1	Eastern main channel and wetlands	Greenfields	Non-developed, with steep upper banks and a wide floodplain gully floor forming riverine wetlands dominated by rushes and sedges.	• Potentially modified hydrographs due to increased impervious surfaces from development. • Potential piping, diversions and/or reclamations of watercourses • Potential exacerbation of existing erosion issues	• Establish native riverine wetland plant communities along gully floor and native riparian buffer species on banks. • Enhance existing native fish habitat and maintain fish passage by utilising best practice infrastructure design.
MZ2	Eastern modified tributaries	Greenfields	Extensive modification of the watercourses, including damming to create series of online ponds. Online ponds have caused changes in base flow, habitat type and availability and biochemical water quality conditions.	• Extensively modified watercourses, with culvert damming. • Potential increased erosion downstream if these ponds are removed	• Naturalisation of these ponds to increase watercourse connectivity and provide upstream fish habitat – needs to consider downstream impacts on erosion. • Utilising existing ponds as part of stormwater. management devices if surrounding topography and location within catchment is suitable.
MZ3	Western and Central tributaries	Brownfield	Modified watercourses with several reaches showing severe erosion scarring and unstable undercut banks.	• Severe erosion noted in many reaches within the management zone • Man-made fish barriers such as culverts	• As part of development, opportunity to stabilise banks, create set-backs, and increase native vegetation. These actions will mitigate further erosion and enhance ecological values. • Good fish habitat present throughout reaches, opportunities to increase ecological value, fish barrier mitigation.
MZ4	Western and Central Main Channel	Brownfield	Generally, have high watercourse shading and low bank erosion scarring. Vegetation along the reaches are predominately exotic with significant infestations of Tradescantia.	• Isolated examples of stormwater infrastructure degradation	• Maintenance of assets; repair or replace bank lining assets identified to be in poor condition, mitigate existing erosion hotspots, repair or replace culverts identified to be in poor condition (rating of 4 or 5).
MZ5	Western and Central Farm drains	Brownfield	Agricultural farm drains, often straightened and deepened with evidence of stock damage.	• Agricultural streams, modified through straightening and deepening • Stock damage is evident in these watercourses	• Promote stock exclusion via fencing. This can be supported by statutory requirements such as the Proposed Healthy Waters Waikato Regional Plan Change 1. Schedule C – stock exclusion. • Working with landowners to promote riparian planting.
MZ6	Eastern tributaries and wetlands	Greenfield	Headwaters and main reaches of the eastern tributaries are low-lying wide floodplain reaches or seepage wetlands often fed by springs. Little overhead cover from vegetation, sparse understory and modified by stock access.	• Low-lying seepage wetlands modified by stock damage and pastoral land use	• As part of the NZTA Southern Links designation, several properties will be acquired by Council. Opportunity to implement effective stormwater design with positive ecological outcomes.

5.2 Erosion Mitigation Projects

The conversion of Greenfield and low density developed Brownfield areas to higher density urban areas will result in an increase in impervious surfaces, and associated changes in the hydrograph of receiving watercourses. These changes in the hydrograph often include 'flashy' hydrology with elevated flow depths and velocity, as well as lower base flows.

Mitigation of frequent flow changes is likely to be incorporated in development proposals, however there will be a residual potential that development will increase the erosion and channel instability downstream. Remediation of current instabilities is important to mitigate this further erosion risk in the sub-catchment resulting from the proposed development. Engineering approaches to remediate channel instabilities include reducing channel bank grade, placement of boulders for bank protection, and planting riparian vegetation buffers. The mitigation projects identified in this assessment arise from existing issues that have the potential to be exacerbated by changes in the contributing catchment, and areas within the Greenfields area which have the potential to be affected be erosion following development.

Where erosion hotspots, 'poor' Pfankuch stability scores, or reaches with erosion scarring > 60% were identified, engineering approaches to mitigate further erosion are recommended (EMP_01 to EMP_15) and are detailed in Table 14. Within the Greenfields area, an assessment was undertaken on the existing condition of the stream and the potential impact to stream erosion that could occur following development (EMP_16 to EMP_31) and are detailed in Table 15. Refer to Appendix 1 for a map showing the location of these projects within the catchment.

The erosion mitigation projects within the Greenfields areas is a high-level assessment based on current geomorphology and observed erosion within similar watercourses in Hamilton following development. The actual effects will be a function of the type of development and management of stormwater that occurs, and the natural factors of vegetation, topography and geology of the reaches. The projects shown should be treated as a guide for future planning, however, the actual scope and location of erosion mitigation projects will likely vary from those shown. Areas not currently designated as an EMP may also require future erosion mitigation projects if actual erosion effects are found to be worse than assumed.

It should be noted that the primary objective of these erosion mitigation projects is to manage existing erosion issues and mitigate residual future erosion effects only. The scope of these erosion mitigation projects does not provide mitigation solutions for agricultural best practices such as stock exclusion to waterways and have therefore not been costed for but have been noted where applicable. The projects do not directly seek but may have co-benefits to improve water quality, ecological enhancement, or amenity values. For enhancement opportunities, which aim to address factors such as ecological and amenity values within the Mangakōtukutuku catchment where erosion mitigation is not the primary driver, refer to in Section 5.3.

High-level costs for the proposed erosion mitigation measures using unit rates and costs applied to erosion mitigation works are derived from quotes and invoices from physical works in the last five years in the Auckland market. The rates are considered representative at the time of writing. The assumptions used to derive each unit cost is outlined in Appendix 2. It is recommended that the final costings presented in this report should be considered as indicative only with detailed options analysis and planning assessment is conducted to inform capital works at the detailed design stage. The sum of the 31 erosion mitigation costs (including physical works, project preparation and contingency) is $ 12,532,000 (Table 16 & Table 17) with further project preparation and contingency costs breakdown in Appendix 3.

The cost estimates also exclude land acquisitions, excavation in solid rock, removal of contaminated material or asbestos, consent or development contributions, funding costs and legal fees, GST and unforeseen ground conditions. Detailed costing will be required at the detailed design stage. The purpose of the costs provided in this report is to indicate relative costings for the purpose of decision making.

Table 14: Proposed Erosion Mitigation Works in the Mangakōtukutuku catchment

Project ID	Location in the catchment	Associated reach length	Issue	Proposed erosion mitigation works	High level costs for physical works
EMP_01	MGK_Main_2	328 m	Fluvial erosion resulting in highly incised, steep stream banks. The subject reach receives discharge from the majority of the upstream contributing catchment. Increases in impervious cover maybe influencing peak discharge which is resulting in channel forming flows, localised erosion and sediment mobilisation.	• Provide toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Replacement of weeds (tradescantia and Japanese walnut) with natives and consideration of staged willow removal	$ 737,000
EMP_02	MGK_E_Main_1	71 m	Fluvial erosion resulting in highly incised, steep stream banks. Constricted, narrow channel, toe erosion and degradation	• Keystone boulders to provide toe protection	$ 105,000
EMP_03	MGK_W_Fork1 MGK_W_Fork1_Trib1	499 m	The channel is narrow and incised with regular slumping, scour and undercut. The reaches are assessed as 40-60% bank erosion scarring or slumping and the bank stability is assessed as fair or good. There is a large erosion hotspot in the lower reach. The upper portion of the subject reach has sparse overhead cover no pine canopy or understorey.	• Provide toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Replacement of weeds such as willows, tradescantia and Japanese walnut with natives	$ 394,000
EMP_04	MGK_C_Trib1_2 to 4	867 m	Much of the reach is classed as having 40-60% erosion along both banks with remaining reaches identified as having landslips and medium overall risk value erosion hotspots. Overall stability score of the upper banks is assessed as fair to poor. There is also significant sediment deposition along the banks.	• Provide toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Replacement of weeds such as willows, tradescantia and Japanese walnut with natives • Mitigate fish barrier to climbing species at culvert outlet beneath path crossing MGk_C_Trib1_2 by installing a fish ladder or spat rope.	$ 703,000
EMP_05	MGK_W_Trib5_1 to 10	857 m	The reach has steep upper banks (10 m high) where residential houses are located. Tradescantia is the dominant ground cover across the floodplain and there are several weed infestations of blackberry and bind weed. The upper reaches of the tributary (MGK_W_Trib5_7) is a concrete lined channel with concrete bank lining which has an impact on flow regimes, resulting in flashy flows and low base flows.	• Increased channel heterogeneity of cobbles and rocks to support fish habitat • Significant weeding and replanting with natives • Naturalisation/removal of the lined channel along MGK_W_Trib5_7	$ 428,000
EMP_06	MGK_W_Trib4_1 to 2	139 m	An incised watercourse with 15 m high steep upper banks. The outlet at Bruce Avenue has a dissipating structure of concrete blocks for a section of the downstream watercourse. There is considerable vegetation overgrowth preventing a full assessment of the asset however it is generally considered that this vegetation may pose a risk during high storm flows and should be cleared.	• Weeding and planting of natives 5m either side of reach to support the regraded banks	$ 52,000
EMP_07	MGK_C_Trib4_1	100 m	The reach consists of an incised channel with approximately 1 m high lower banks. The upper banks are approximately 8 m high. The reach has high bank erosion scarring (>60% reach length) and a poor overall upper bank stability score. Down-cutting and channel widening is occurring along this reach which is likely a result of the piped discharge from the surrounding residential areas.	• Toe protection to banks and along channel while increasing channel heterogeneity of cobbles and rocks • Bank regrading to 3:1 slope • Planting of native understory along regraded banks	$ 242,000
EMP_08	MGK_W_Main_12	133 m	Ongoing erosion resulting in highly incised, steep stream banks.	• Toe protection to banks • Regrading of banks • Planting of native understory along regraded banks	$ 231,000
EMP_09	MGK_C_Fork1_1	35 m	The outlet of the triple culvert under state highway 3 has a concrete headwall with an informal timber lining above one of the culvert headwalls which extends along the upper true left bank for approximately 12 m. The lining is assessed to have a high risk of collapsing and maintenance is required. Erosion is occurring at the outlet of these culverts.	• Newbury Rock riffle • Keystone boulders • Grade control	$ 113,000
EMP_10	MGK_E_Main_3 to 5 MGK_E_Trib2_1 to 3	160 m	Constricted, narrow channel with wide floodplains. High sedimentation in the stream channel. To increase the ecological and biodiversity value of the watercourse, tradescantia in the lower reach and that the riparian margins of the entire reach should planted with appropriate native flora.	• Weeding and planting of native understory along regraded banks	$ 56,000
EMP_11	MGK_Main_7 to 8, MGK_E_Trib3 MGK_Trib4_1	378 m	Fluvial erosion resulting in highly incised, steep stream banks.	• Toe protection along channel • Weeding and planting of natives 5m either side of reach to support the regraded banks	$ 296,000

Project ID	Location in the catchment	Associated reach length	Issue	Proposed erosion mitigation works	High level costs for physical works
EMP_12	MGK_C_TRIB2_1	35 m	Incised lower banks, steep upper banks – 20 m high. High (> 60% of reach) erosion with loose sediment deposition with low flow, Woody debris creating pooling and localised flooding. Limited vegetation on floodplains.	• Bank batter to regrade banks to a 3:1 slope • Erosion planting • Retaining • Toe protection	$ 112,000
EMP_13	MGK_C_MAIN_4	160 m	Unstable bank undercutting and slumping along reach. Poor water clarity. Timber lining extending approx. 30 m in the lower reaches. Thick tradescantia weedy ground cover, with limited riparian vegetation.	• Bank batter • Erosion planting • Toe protection	$ 598,000
EMP_14	MGK_C_FORK1_2	290 m	Steep incised channel along lower reach. Bank undercutting and slumping, Debris including concrete blocks present in stream channel.	• Bank batter • Erosion planting • Toe protection	$ 587,000
EMP_15	MGK_E_TRIB3_1 MGK_W_TRIB3_1	24 m	Severe bank erosion, scouring and slumping along entire reach length. Unstable banks with limited vegetation. Large woody debris in stream channel has significantly altered the hydrology of the reach. Thick tradescantia ground cover.	• Bank batter • Erosion planting	$ 17,000
Total					$ 4,671,000

Table 15: Proposed Future Erosion Mitigation Works in the Mangakōtukutuku catchment

Project ID	Location in the catchment	Associated reach length	Potential Issues Following Development	Proposed erosion mitigation works	High level costs for physical works
EMP_16	MGK_E_MAIN_2 to 4	854 m	Defined channel that may experience downcutting and widening with a change in stream hydrograph Stream banks will likely steepen and be susceptible to mass slumping. Fluvial erosion to stream banks is likely to increase, especially in areas of higher velocity flow, such as the outside of bends, constriction points, and at debris jams. Areas lacking in vegetation will likely experience increase erosion. Grade control may be required to maintain floodplain engagement.	• Erosion planting • Bank regrading • Toe protection • Grade control structures	$788,000
EMP_17	MGK_E_Trib1_1 to 2	206 m	Defined channel within wetland area. May experience downcutting and removal of accumulated sediment. This will steepen bank grades, which can lead to bank slumping. Fluvial erosion is likely to increase, especially in areas of higher velocity flow such as the outside of bends, constriction points, and at debris jams. Grade control structures may be required to reduce flow velocity and to maintain engagement with the wetlands.	• Bank batter • Toe protection • Grade control structures	$175,000
EMP_18	MGK_E_Trib1_3 MGK_E_TRIB1a_1	278 m	Narrow channel that may experience downcutting and widening, and leading to steep bank grades, increase fluvial erosion and the potential for mass slumping. Lack of vegetation will increase soil susceptibility to erosion. Grade control structures may be required to reduce flow velocity due to the steep grade.	• Erosion planting • Bank regrading • Toe protection • Grade control structures	$348,000
EMP_19	MGK_E_Trib1_4 to 5	218 m	The lack of vegetation will make the soils susceptible to fluvial erosion and potential downcutting.	• Erosion planting	$79,000
EMP_20	MGK_E_TRIB2_3 to 4	107 m	Currently a wetland area with sediment build up. Changes in the stream hydrograph may result in the sediment flushing out, which would lead to widening and downcutting of the stream. Grade control recommended to reduce flow velocity and minimise risk of loss of sediment.	• Erosion Planting • Bank batter • Grade control	$129,000
EMP_21	MGK_E_MAIN_7	178 m	Currently a wetland reach. Changes in the stream hydrograph may result in downcutting of the channel and increased fluvial erosion to the banks, particularly on the outside of bends, constriction points and at debris jams.	• Bank batter • Toe protection	$130,000
EMP_22	MGK_E_TRIB3_2 to 3	477 m	Currently a shallow channel that may begin to down cut following a change to stream hydrograph. This may lead to mas slumping of banks and increase fluvial erosion and channel widening.	• Erosion planting • Bank batter	$195,000
EMP_23	MGK_E_TRIB4_1	204 m	Shallow, meandering channel. Increased fluvial erosion is expected to occur, especially in areas of higher velocity such as outside bends, constriction points and at debris jams.	• Erosion planting • Bank Batter • Toe protection	$145,000
EMP_24	MGK_E_MAIN_9	511 m	Defined channel that may experience downcutting and widening with a change in stream hydrograph. This may result in mass slumping of stream banks and an increase in fluvial erosion especially in areas of higher velocity flow, such as the outside of bends, constriction points, and at debris jams.	• Bank batter • Toe protection	$362,000

Project ID	Location in the catchment	Associated reach length	Potential Issues Following Development	Proposed erosion mitigation works	High level costs for physical works
EMP_25	MGK_E_TRIB6_2 to 3 MGK_E_TRIB6a_1	501 m	Incised channel that may experience downcutting and widening with a change in stream hydrograph. This may result in increased fluvial erosion and mass slumping of banks, particularly in areas of higher velocity such as the outside of bends and constriction points.	• Erosion planting • Bank batter • Toe protection	$269,000
EMP_26	MGK_E_TRIB6_4 to 5	358 m	Shallow channel that may experience downcutting and widening and removal of built up sediment with a change in stream hydrograph. This may result in increased fluvial erosion and mass slumping of banks, particularly in areas of higher velocity such as the outside of bends and constriction points.	• Erosion planting • Bank batter	$103,000
EMP_27	MGK_E_MAIN_11 to 12	576 m	Defined channel that may experience downcutting and widening with a change in stream hydrograph. This may result in increased fluvial erosion and mass slumping of banks, particularly in areas of higher velocity such as the outside of bends and constriction points and debris jams.	• Bank batter • Toe protection	$417,000
EMP_28	MGK_E_MAIN_13 t0 15	564 m	Wide flood plain with pools and sediment accumulation, and existing drainage ditch removing flow from the stream. A change in stream hydrograph will likely removal built up sediment and lead to additional fluvial erosion and downcutting, particularly in areas of higher velocity such as the outside of bends and constriction points and debris jams.	• Erosion planting • Bank batter • Toe protection	$443,000
EMP_29	MGK_E_TRIB8_1	211 m	Shallow, wetland area with a channel starting to become defined. A change in stream hydrograph is expected to increase fluvial erosion, leading to downcutting and widening.	• Erosion planting • Bank batter	$98,000
EMP_30	MGK_E_MAIN_16 to 17	154 m	An artificially straightened channel with sharp bends. Increased flow volumes and velocity expected to increase fluvial erosion, particularly in areas of higher velocity, such as the outside of bends and constriction points and debris jams. This could result in mass wasting of side slopes.	• Erosion planting • Bank batter • Toe protection	$72,000
EMP_31	MGK_E_TRIB7_2	75 m	Currently this is a wetland reach with a pond upstream. Flow volume and velocity is expected to increase following development, especially upstream where the pond may provide stormwater attenuation. Increased fluvial erosion and downcutting is expected to occur.	• Erosion planting • Bank batter • Toe protection	$63,000
Total					$ 3,816,000

Table 16: Proposed erosion mitigation works costs ($ rounded to nearest $000)

Project ID	Bank Batter Excavation	Coir Matting	Planting	Keystone Boulders	Newbury Rock Riffle	Toe Protection	Physical Works Total*	Project Preparation**	Total including 20% Contingency
EMP_01	408,000	48,000	100,000			181,000	737,000	170,000	1,088,000
EMP_02				105,000			105,000	25,000	156,000
EMP_03	70,000	15,000	179,000			130,000	394,000	90,000	581,000
EMP_04	185,000	38,000	307,000			173,000	703,000	161,000	1,037,000
EMP_05	46,000	9,000	287,000			86,000	428,000	99,000	632,000
EMP_06			52,000				52,000	12,000	77,000
EMP_07	124,000	12,000	37,000			69,000	242,000	55,000	356,000
EMP_08	105,000	15,000	46,000			65,000	231,000	53,000	341,000
EMP_09			5,000	98,000	10,000		113,000	25,000	166,000
EMP_10			56,000				56,000	14,000	84,000
EMP_11	31,000	5,000	132,000			128,000	296,000	69,000	438,000
EMP_12	27,000	4,000	14,000	50,000		17,000	112,000	25,000	164,000
EMP_13	271,000	31,000	150,000			146,000	598,000	138,000	883,000
EMP_14	198,000	29,000	97,000			263,000	587,000	136,000	868,000
EMP_15	7,000	2,000	8,000				17,000	5,000	26,000
Total							$ 4,671,000	$ 1,077,000	**$ 6,897,000**

** Unit rates used to calculate costs are in Appendix 2*

*** Resource consent, design, feasibility, and Liability costs breakdown in Appendix 3*

Table 17: Proposed future erosion mitigation works costs ($ rounded to nearest $000)

Project ID	Bank Batter Excavation	Coir Matting	Planting	Keystone Boulders	Newbury Rock Riffle	Toe Protection	Physical Works Total*	Project Preparation**	Total including 20% Contingency
EMP_16	200,000	30,000	61,000		97,000	400,000	788,000	182,000	1,164,000
EMP_17	24,000	5,000			84,000	62,000	175,000	41,000	259,000
EMP_18	18,000	4,000	100,000		176,000	50,000	348,000	80,000	514,000
EMP_19			79,000				79,000	18,000	116,000
EMP_20	6,000	1,000	20,000		102,000		129,000	30,000	191,000
EMP_21	43,000	6,000				81,000	130,000	30,000	192,000
EMP_22	21,000	5,000	169,000				195,000	46,000	289,000
EMP_23	23,000	5,000	55,000			62,000	145,000	34,000	215,000
EMP_24	120,000	11,000				231,000	362,000	83,000	534,000

EMP_25	46,000	11,000	136,000	76,000	269,000	62,000	397,000
EMP_26	27,000	12,000	64,000		103,000	23,000	151,000
EMP_27	137,000	19,000		261,000	417,000	97,000	617,000
EMP_28	129,000	19,000	40,000	255,000	443,000	101,000	653,000
EMP_29	16,000	5,000	77,000		98,000	23,000	145,000
EMP_30	9,000	2,000	42,000	19,000	72,000	16,000	106,000
EMP_31	9,000	2,000	29,000	23,000	63,000	14,000	92,000
Total					$ 3,816,000	$ 880,000	**$ 5,635,000**

** Unit rates used to calculate costs are in Appendix 2*

*** Resource consent, design, feasibility, and Liability costs breakdown in Appendix 3*

5.3 Enhancement Opportunities

A total of 19 enhancement opportunities have been identified in the Mangakōtukutuku catchment. Some enhancement projects are intended to work in tandem with the proposed erosion mitigation works to improve management outcomes. Other enhancement projects highlight opportunities to utilise best practice green infrastructure design to minimise adverse impacts on watercourses, particularly in areas of Greenfield development. Enhancement opportunities are intended to increase the amenity and ecological value of the watercourses, while improving flow conveyance and improving resistance to further changes to surrounding land use.

The enhancement projects identified in this assessment represent opportunities only. The enhancement information has value as it can inform a range of parties (e.g. HCC, WDC, WRC, landowners) who may be considering or undertaking other works in the vicinity. Parties will be able use this information to, if they choose, influence project scoping to deliver or maximise environmental benefits, perhaps with no significant additional investment required. Identifying these opportunities also provides an information base for not-for-profit or environmentally focused delivery agencies looking for opportunities to invest in environmental improvement works (e.g. Streamcare groups such as Mangakōtukutuku Stream Care Group, Mangakōtukutuku Puna Koiora Trust, WRC, WRA).

The enhancement opportunities are located on both public (i.e. Council-owned) and private land. For some of these enhancement opportunities to be realised, co-operation with landowners will be required and, in some cases, easements developed for maintenance of these areas. In the prioritisation of enhancement opportunities, projects located on private land have been scored as lower priority. The prioritisation scores and description of these enhancement projects is presented in Table 18.

The majority of these enhancement opportunity projects focus on ecological planting along riparian corridors of streams. Riparian planting along these corridors would enhance potential inanga spawning habitat and ecological connectivity in the catchment. The estimated cost of the enhancement opportunity is approximated at $35,282,000. This cost does not include pricing for proposed enhancement projects EO18 and EO19. For EO18 and EO19 it is recommended that an engineering evaluation is undertaken at the site to understand the impacts of the construction of multiple large offline and online ponds using concrete dams on the property. The two main enhancement opportunities for EO18 and EO19 include;

1. Re-instating a natural watercourse including removal of dams and culverts, increased riparian planting and naturalisation; or,
2. Naturalisation of the terraced ponds/ wetlands. This option would include the removal of the large informal dam structures and adaption of best practice design for inlet and outlet points.

It is recommended that HCC work closely with the landowners to ensure that these ponds, which appear to be non-consented receive consent approval or are remediated. The remediation would enhance the watercourses by re-introducing natural hydrology consisting of riffle/run sequences, and removal of fish barriers.

As per the REM methodology (HCC, 2015), each enhancement opportunity is assigned a high-level prioritisation score based on the potential benefits to the public and local amenity values, ecological values such as biodiversity and habitat improvements, and flow conveyance. Prioritisation scores range from 1 – 4, with 4 indicating that the potential project will significantly improve the environment. The individual values for amenity, ecological and conveyance values were summed, and an overall priority was calculated.

In addition, high-level costs for the proposed works within each project are presented in Table 19. These costs are calculated using the same unit rates used for the erosion mitigation projects. The assumptions

used to derive each unit cost is outlined in Appendix 2. The unit rates and costs applied to enhancement opportunity projects are derived from quotes and invoices from physical works in the last five years in the Auckland market. The rates are considered representative at the time of writing. The assumptions used to derive each unit cost is outlined in Appendix 2. The final costings presented in this report should be considered as indicative only with further refinement required at the detailed design stage.

The cost estimates also exclude land acquisitions, excavation in solid rock, removal of contaminated material or asbestos, consent or development contributions, funding costs and legal fees, GST and unforeseen ground conditions. Detailed costing will be required at the detailed design stage. The purpose of the costs provided in this report is to indicate relative costings for the purpose of decision making.

Table 18: Summary of enhancement opportunities and their prioritisation

Project ID	Location in the catchment	Land Ownership	Description	Amenity	Ecology	Conveyance	Overall Score	Prioritisation Score	High level costs
EO 1	Main	Public	Potential good spawning habitat, dense weed cover dominated by willow, privet and Tradescantia weed.	3	3	2	8	4 – High	$ 191,000
EO 2	Main	Public	Narrow channel showing some signs of erosion susceptibility, with protective measures such as coir matting.	2	2	3	7	3 – Moderate	$ 54,000
EO 3	Central Sub-catchment	Public	Potential good habitat for native Kokopu. Extensive sediment deposition and signs of erosion susceptibility. removal of culvert would enhance fish passage.	2	4	2	8	4 – High	$ 240,000
EO 4	Central Sub-catchment	Private	Straightened and potentially deepened channel. Grasses and weeds prevalent along reach, pastoral land use. Naturalisation of the channel, weed control and erosion protection would enhance this section of the catchment.	2	3	2	7	3 – Moderate	$ 364,000
EO 5	Eastern Sub-catchment	Private	Some good macroinvertebrate taxa present, potential good in-stream habitat. Riparian planting, particularly along TRB, would enhance stream conditions.	2	4	2	8	4 – High	$ 1,153,000
EO 6	Eastern Sub-catchment	Mixed	Incised watercourse with 15 m high steep upper banks. Overhead shading of the watercourse is good (> 70%). Significant tradescantia cover along banks and riparian extent. There are several locations of illegal litter dumping and the weedy vegetation may present a risk to asset.	3	3	3	9	4 – High	$ 4,326,000
EO 7	Eastern Sub-catchment	Mixed	Upstream sections owned by private landowners, need to consider engagement with HCC to work collaboratively. The project is located in close proximity to the central interchange of the Southern Links roading project at 112 Peacockes Lane. The reaches are small, incised watercourses.	1	3	2	6	3 – Moderate	$ 2,876,000
EO 8	Eastern Sub-catchment	Mixed	Reaches characterised as defined gully banks (>20 m), wide wetland floodplains and meandering channel along the gully floor. The upper reach if a culverted farm pond. The vegetation along this section includes an understorey of willow, weed infestations (including blackberry, tradescantia, and gorse) carex grasses or rush wetlands with pine canopy along the upper banks near the central channel.	1	3	1	5	3 – Moderate	$ 3,754,000
EO 9	Eastern Sub-catchment	Private	Reaches are defined as gully systems with high, steep banks (> 10 m height), wide wetland floodplains and meandering channels. The vegetation is predominately exotic willow with weed infestations including blackberry, tradescantia, and gorse. Weed control and planting riparian vegetation to enhance the existing ecological values.	1	3	1	5	3 – Moderate	$ 1,747,000
EO 10	Eastern Sub-catchment	Private	Reaches are defined as gully systems with high, steep banks (> 10 m height), wide wetland floodplains and meandering channels. The vegetation is predominately exotic willow with weed infestations including blackberry, tradescantia, and gorse. Weed control and planting riparian vegetation to enhance the existing ecological values.	1	3	1	5	3 – Moderate	$ 554,000
EO 11	Eastern Sub-catchment	Private	Reaches are defined as gully systems with high, steep banks (> 10 m height), wide wetland floodplains and meandering channels. The vegetation is predominately exotic willow with weed infestations including blackberry, tradescantia, and gorse. Weed control and planting riparian vegetation to enhance the existing ecological values.	1	3	1	5	3 – Moderate	$ 455,000
EO 12	Eastern Sub-catchment	Private	Reaches are defined as gully systems with high, steep banks (> 10 m height), wide wetland floodplains and meandering channels. The vegetation is predominately exotic willow with weed infestations including blackberry, tradescantia, and gorse. Weed control and planting riparian vegetation to enhance the existing ecological values.	1	3	1	5	3 – Moderate	$ 1,134,000
EO 13	Eastern Sub-catchment	Private	The watercourse is incised with wide floodplains with numerous wetland seeps and springs along the floodplains and dense macrophyte cover. Deep sedimentation and the lower reaches are impacted by stock damage. Enhancement through maximising riparian buffer width.	1	3	1	5	3 – Moderate	$ 5,200,000
EO 14	Eastern Sub-catchment	Private	The watercourse has wide floodplains with areas of defined channel and the banks have a gradual slope. The watercourse shows signs of stock damage, exclusion fencing, and riparian planting would improve the ecological condition of the reach.	1	2	1	4	2 – Low	$ 1,414,,000
EO 15	Eastern Sub-catchment	Private	Extensive stock damage has caused deterioration of the stream channel morphology. No defined channels and hydrologically functions as a wetland.	1	2	1	4	2 – Low	$ 1,668,000
EO 16	Eastern Sub-catchment	Private	The reach includes exotic weed species. The section could be enhanced through weed control and planting, fencing and stock exclusion. There are opportunities to work with the land owners to enhance the riparian habitat and promote connectivity in the catchment.	1	2	2	5	3 – Moderate	$ 592,000

Project ID	Location in the catchment	Land Ownership	Description	Amenity	Ecology	Conveyance	Overall Score	Prioritisation Score	High level costs
EO 17	Eastern Sub-catchment	Private	Series of online and offline ponds dominated by aquatic weeds and stagnant flows. Multiple fish barriers present for upstream populations. Re-instating watercourse or wetland from culverted ponds or consider as treatment device locations.	2	3	3	8	4 – High	$ 1,951,000
EO 18	Eastern Sub-catchment	Private	Series of four online ponds (totalling 3.6 Ha) and multiple offline ponds dominated by aquatic weeds and stagnant flows. Multiple fish barriers present for upstream populations due to the construction of informal concrete and earth dams. Four dams up to 6 m width (parallel to flow) and 2 5m length (perpendicular to flow) have created ponds with significant drops (2 – 4 m) reducing connectivity in the watercourse. Enhancement opportunity options may include: Re-instating a natural watercourse including removal of dams and culverts, increased riparian planting and naturalisation; or, Naturalisation of the terraced ponds/wetlands. This enhancement option would include removal of the four informal large dam structures.	3	4	3	10	4 – High	A full cost estimate for EO18 has not been provided due to the scale of the proposed works. It is recommended that an options assessment and landowner liaison be undertaken prior to cost estimates being undertaken.
EO 19	Eastern Sub-catchment	Private	Series of online and offline ponds dominated by aquatic weeds and stagnant flows. Multiple fish barriers present for upstream populations. Re-instating watercourse or wetland from culverted ponds or consider as treatment device locations.	2	3	3	8	4 – High	A full cost estimate for EO19 has not been provided due to the scale of the proposed works. It is recommended that an options assessment and landowner liaison be undertaken prior to cost estimates being undertaken.

Table 19: Summary of enhancement opportunity costs (rounded to nearest $000)

Enhancement Opportunity	Planting	Pond Naturalisation	Contingency (20%)	Total
EO 1	$ 191,000		$ 38,000	$ 229,000
EO 2	$ 54,000		$ 11,000	$ 65,000
EO 3	$ 240,000		$ 48,000	$ 288,000
EO 4	$ 364,000		$ 73,000	$ 437,000
EO 5	$ 1,153,000		$ 231,000	$ 1,384,000
EO 6	$ 4,326,000		$ 865,000	$ 5,191,000
EO 7	$ 2,876,000		$ 575,000	$ 3,451,000
EO 8	$ 3,754,000		$ 751,000	$ 4,505,000
EO 9	$ 1,747,000		$ 349,000	$ 2,096,000
EO 10	$ 554,000		$ 111,000	$ 665,000
EO 11	$ 455,000		$ 91,000	$ 546,000
EO 12	$ 1,134,000		$ 227,000	$ 1,361,000
EO 13	$ 5,200,000		$ 1,040,000	$ 6,240,000
EO 14	$ 1,414,000		$ 283,000	$ 1,697,000
EO 15	$ 1,668,000		$ 334,000	$ 2,002,000
EO 16	$ 592,000		$ 118,000	$ 710,000
EO 17	$ 1,821,000	$ 130,000	$ 390,000	$ 2,341,000[1]
EO 18	$ 1,229,000	Refer to notes[2]	$ 246,000	Refer to notes[2]
EO 19	$ 499,000	Refer to notes[3]	$ 100,000	Refer to notes [3]
Total (excluding Pond naturalisation of EO18 and EO19)				**$ 35,282,000**

[1] Excavation: 1000 m3; Rock lining at $ 600, 150 m3; Reintroduction of 11 riffles at 6 m2 = 66 m2 to connect the isolated farm ponds; Rock riffle at average depth of 0.5 m3, at 70 m3.

[2] A full cost estimate for EO18 has not been provided due to the scale of the proposed works. It is recommended that an options assessment and landowner liaison be undertaken prior to cost estimates being undertaken.

[3] A full cost estimate for EO19 has not been provided due to the scale of the proposed works. It is recommended that an options assessment and landowner liaison be undertaken prior to cost estimates being undertaken.

6.0 Issues and Opportunities Prioritisation.

The information collected through this project has been incorporated into the Stormwater Master Plan version 2 [SMPv2] as both tabulated and spatial information. The below information was incorporated into the Issues and Opportunities [I&O] Register and ranked in accordance with the related criteria:

- All ecolines with the associated erosion classification
- Hot spots with overall risk score
- Fish barriers

All projects described in this report, including their costings, have been recorded in the SMPv2 Projects Database. Where applicable the I&O Register ranking has been associated with each individual project. The SMPv2 Receiving Environment Projects Database collates and prioritises watercourse protection and restoration at a citywide level.

Due to the tabulated and spatial format of the SMPv2 data, the Mangakōtukutuku Receiving Environment I&O Register and Project Database have not been appendices to this report but have been supplied as a separate resource for the ICMP.

7.0 Cost allocation of Erosion Mitigation Projects

Hamilton City Council has the ability to request financial contribution towards watercourse protection and restoration. As per the HCC erosion cost allocation method the following costs have been calculated for Greenfield contribution proportion (Table 20).

Table 20: Erosion cost allocation for Mangakōtukutuku

Erosion Mitigation Project Total	$12,532,000
Contributing Brownfield & Consented Area	573 ha
Contributing Greenfield Area	500 ha
Level of Service Impact	36%
Growth Impact	64% (23% Infill growth, 41% Greenfield growth)
Greenfield Growth Total	$ 5,170,800
Greenfield Growth Allocation	**$ 10,333 per ha**

8.0 Conclusions

Impacts on the freshwater ecosystems through future land use change in the Eastern sub-catchment are a key issue for the Mangakōtukutuku catchment. The Greenfield development process must consider the future pressures and potential impacts on watercourses and the receiving environment. These pressures include:

- Change in land use and the associated contaminants of concern;
- Increased imperviousness and associated changes in hydrograph and impacts on watercourses, including increased potential for channel erosion and reduced base flows; and,
- Further potential barriers to fish passage with the development of more roads and associated culvert structures.

Six management zones were identified based on common pressures and impacts on watercourses which collectively include:

- Increased imperviousness and associated changes in hydrograph and impacts on watercourses, including increased potential for channel erosion and reduced base flows; and,
- Existing fish passage barriers and potential barriers to fish passage with the development of more roads and associated culvert structures.
- Change in land use and the associated contaminants of concern.
- Loss of riparian margin vegetation.
- Stock access to waterways.
- Drainage and piping of freshwater systems.
- Online farm ponds.

The erosion mitigation projects highlight areas of immediate concern and provide remediation options to address localised issues, as well as looking at future erosion issues from Greenfields development. The 31 erosion mitigation projects have been developed at a high level and consist of remediation types such as grade control, erosion planting, bank regrading and toe protection. Generally, the projects that identified areas of existing erosion (EMP_1 to EMP_15) are located along the main channels of the central and western Mangakōtukutuku sub-catchments within the Brownfields area, with the exception of projects EMP_10 and EMP_11. These areas were identified as the most prone to erosion during the watercourse assessment with several reaches showing high erosion scarring and unstable undercut banks. These reaches currently receive flows from the stormwater network via several outlet structures, with inputs expected to increase with development in the area. It is recommended that erosion mitigation projects in these areas are prioritised.

Erosion mitigation projects have also been designated within the Greenfields area (EMP_16 to EMP_31) and are based on the predicted erosion effects from increased flow volumes and velocity within the streams. Any increase in erosion will only be observed in the years following development. The design of the stormwater network, including flow attenuation devices and outfall structures will be an important factor in managing the effects of development on stream erosion.

The total estimated costs including contingency of the physical works for the proposed erosion mitigation projects (current erosion projects and future projects) is approximately $ 12,532,000.

A total of 19 enhancement opportunities have been proposed within the Mangakōtukutuku catchment. These projects highlight enhancement opportunities for the developer, private landowners and Council to increase the ecological and amenity values of the watercourse, whilst enhancing flow conveyance and improving resilience against further changes to surrounding land use. The estimated cost of the

enhancement projects (excluding EO18 and EO19) is approximately $ 35,282,000. The final costings presented in this report should be considered as indicative only with further refinement required at the detailed design stage. The purpose of the costs provided in this report is to indicate relative costings for decision making.

The enhancement opportunities focus primarily on enhancement planting along stream corridors. Most of the enhancement opportunities emphasising ecological planting in the Eastern sub-catchment can be incorporated into the Southern Links implementation works. This will be part of implementing an Ecological Monitoring and Management (EMMP) as required by the conditions of the Southern Links designation (which requires at least 11.8 ha of restoration).

8.1 Recommendations for the ICMP

Through the development of this Watercourse Assessment Report, the requirements for additional investigations and considerations have been identified to inform the wider ICMP. These include:

- Hydrogeology investigation in the eastern Peacocke sub-catchment to understand groundwater processes of springs and seepages with objectives to maintain baseflows for ecological outcomes and inform geotechnical risk.
- Further investigation into the interaction between increased volumes and the erosion risk in the eastern Peacocke sub-catchment.
- Flood storage within the gully and impact on road crossings including investigating issues such as inadvertent dam failure risk under flood conditions.
- Top of gully bank management including possible set back of development for geotechnical risk and management of stormwater for overland flow.
- Management and control of stormwater discharge within the gully including outfall erosion protection.

It is therefore recommended that detailed design of watercourse works and detailed pricing is undertaken as a future action. This would include using existing information on these reaches collected as part of this watercourse assessment together with specific technical investigation undertaken as part of the ICMP. These investigations include:

- Flood modelling outputs (estimated increases in flow and volumes along the network for post development),
- Stormwater management toolbox (development of appropriate works including extended detention),
- Geotechnical and hydrogeology reviews (information of gully form, groundwater interaction and bank crest stability).
- Following this exercise, detailed design and revised costs can be identified for the Peacockes sub-catchment gully network for specific projects.

The Mangakōtukutuku Watercourse Assessment and this report provides Hamilton City Council with valuable knowledge and understanding of the existing state of the Mangakōtukutuku watercourse.

9.0 References

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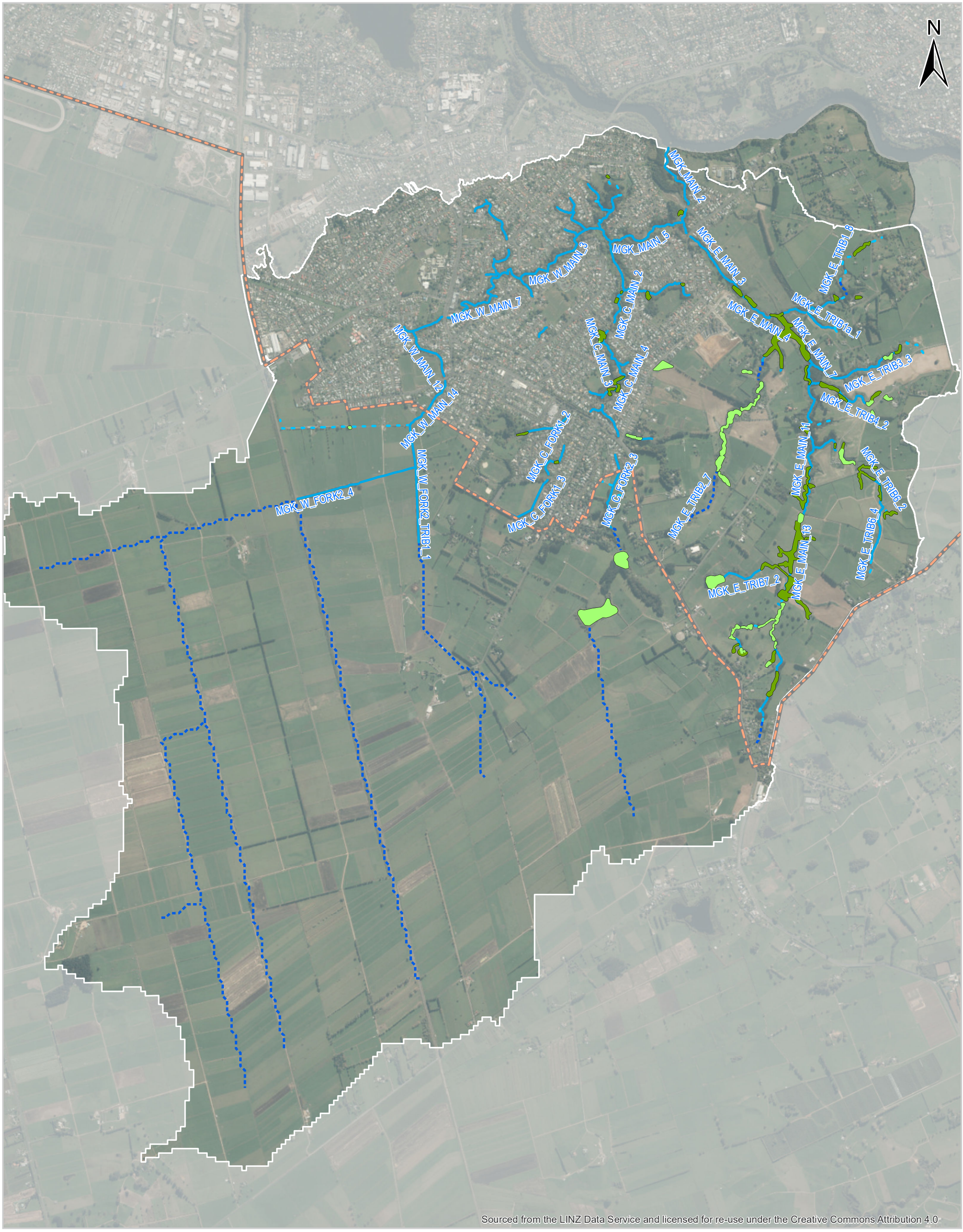
Appendix 1 Maps

MAP 1 - CATCHMENT OVERVIEW

MORPHUM ENVIRONMENTAL LTD



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Ecoline

- Ephemeral
- Perennial
- Watercourse - not assessed

Wetland Type

- Natural
- Artifical

- Stormwater Catchments
- HCC Boundary

HAMILTON CITY COUNCIL

MANGAKŌTUKUTUKU WAR

0 500 1,000 m

Project no. P01236

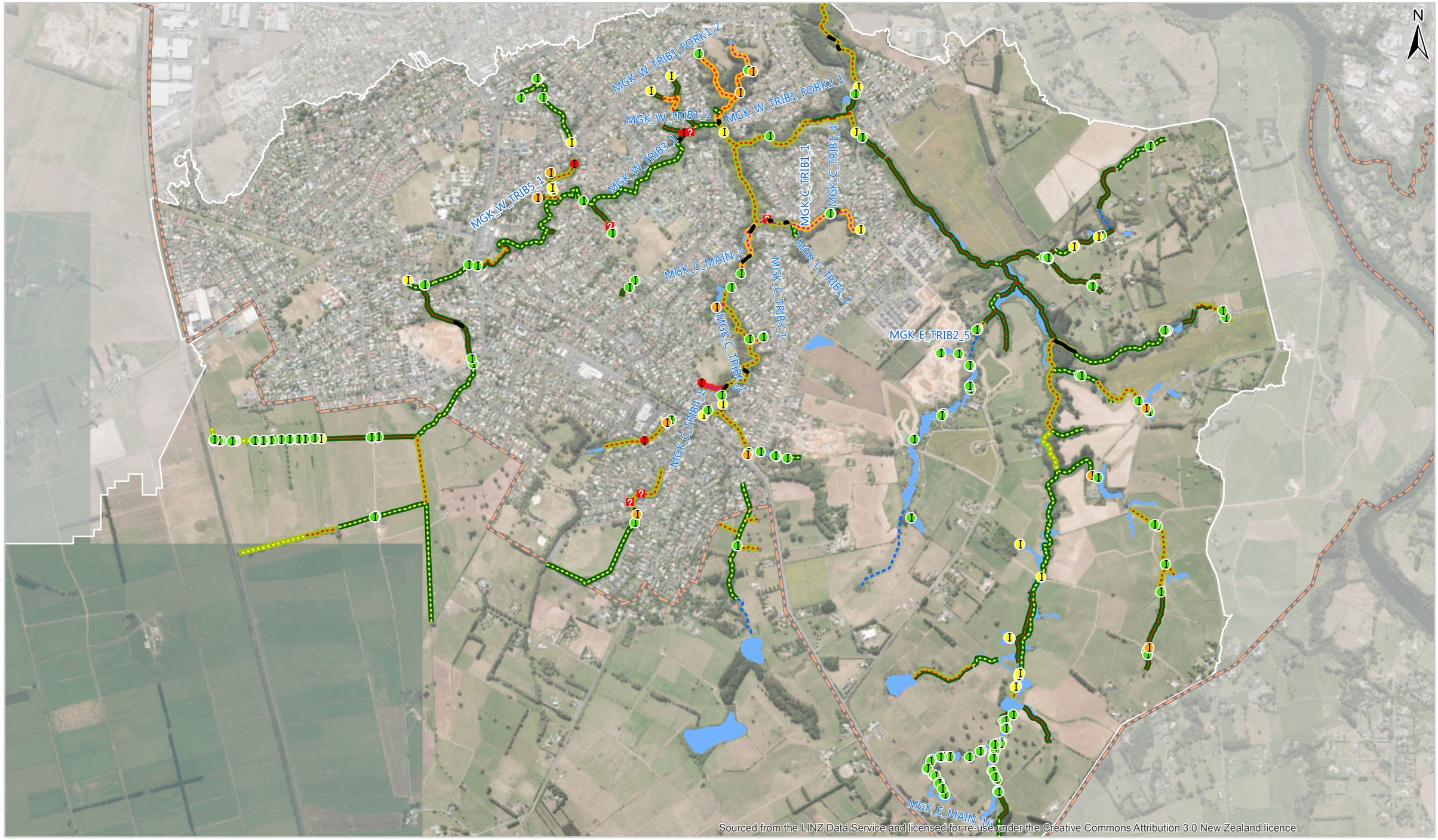
Date 13 Feb 2020

Drawn RY

Approved CU

Map 2 – Engineering Assets and Erosion

MAP 2 - ENGINEERING ASSETS AND EROSION



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Upper Bank Stability
- Excellent
- Good
- Fair
- Poor

Erosion Scars
- <20%
- 20-40%
- 40-60%
- >60%

Inlet/Outlet Erosion
- None
- Slight
- Moderate
- Severe

- Land Slide/Slip
- Erosion Hotspot
- Watercourse - not assessed
- Wetland / Pond
- Stormwater Catchments
- HCC Boundary

Client HAMILTON CITY COUNCIL
Project **Mangakotukutuku WAR**

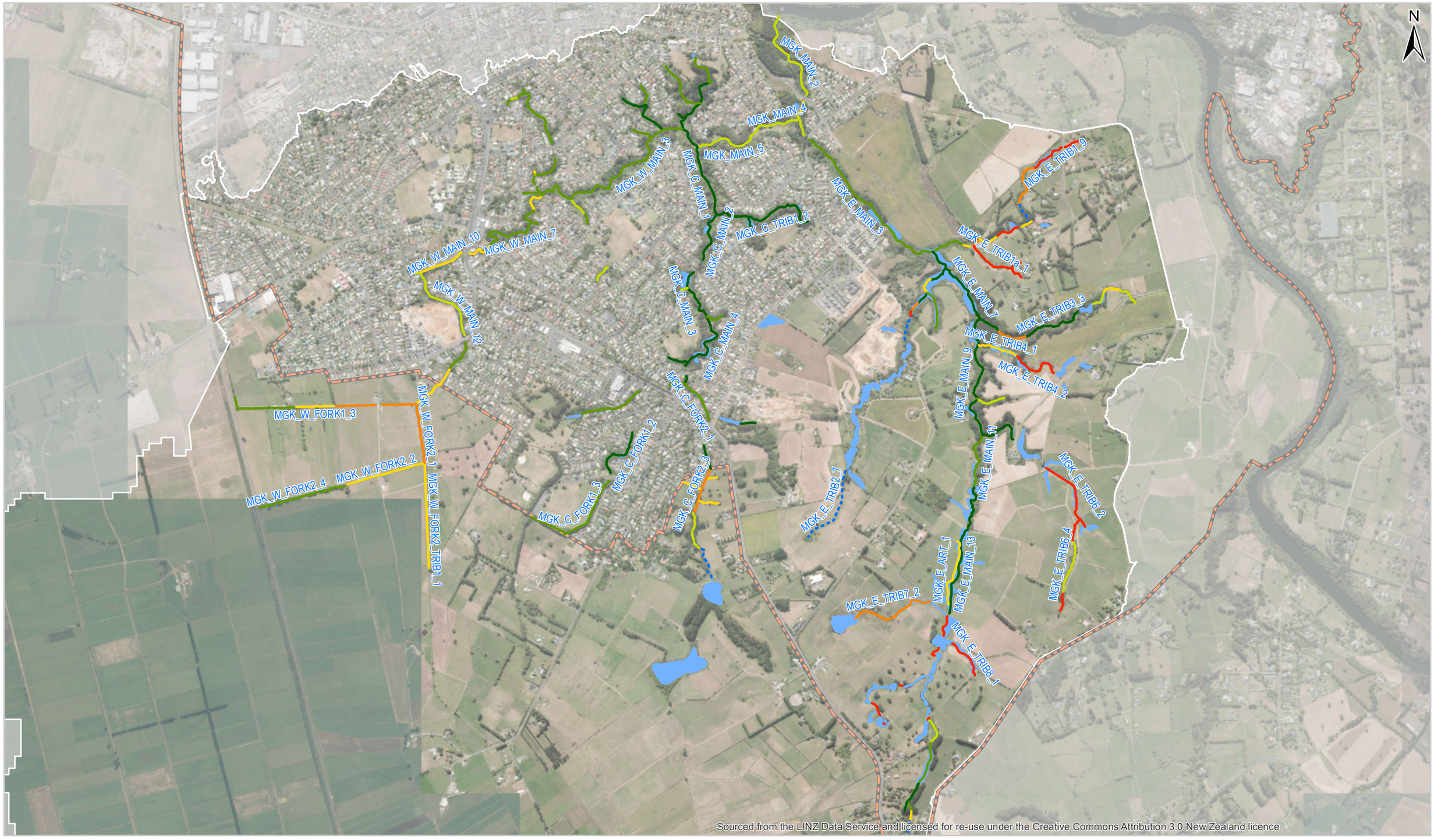
0 750 1,500 m

Project no. P01236
Date 16 Jun 2017
Drawn CU
Approved ER

Map 3 – Riparian Overhead Cover

MAP 3 - RIPARIAN OVERHEAD COVER

MORPHUM ENVIRONMENTAL LTD



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Overhead Shading

- <10%
- 10-30%
- 30-50%
- 50-70%
- 70-90%
- >90%
- Watercourse - not assessed
- Wetland / Pond
- Stormwater Catchments
- HCC Boundary

Client HAMILTON CITY COUNCIL

Project **Mangakotukutuku WAR**

0 750 1,500 m

Project no. P01236

Date 16 Jun 2017

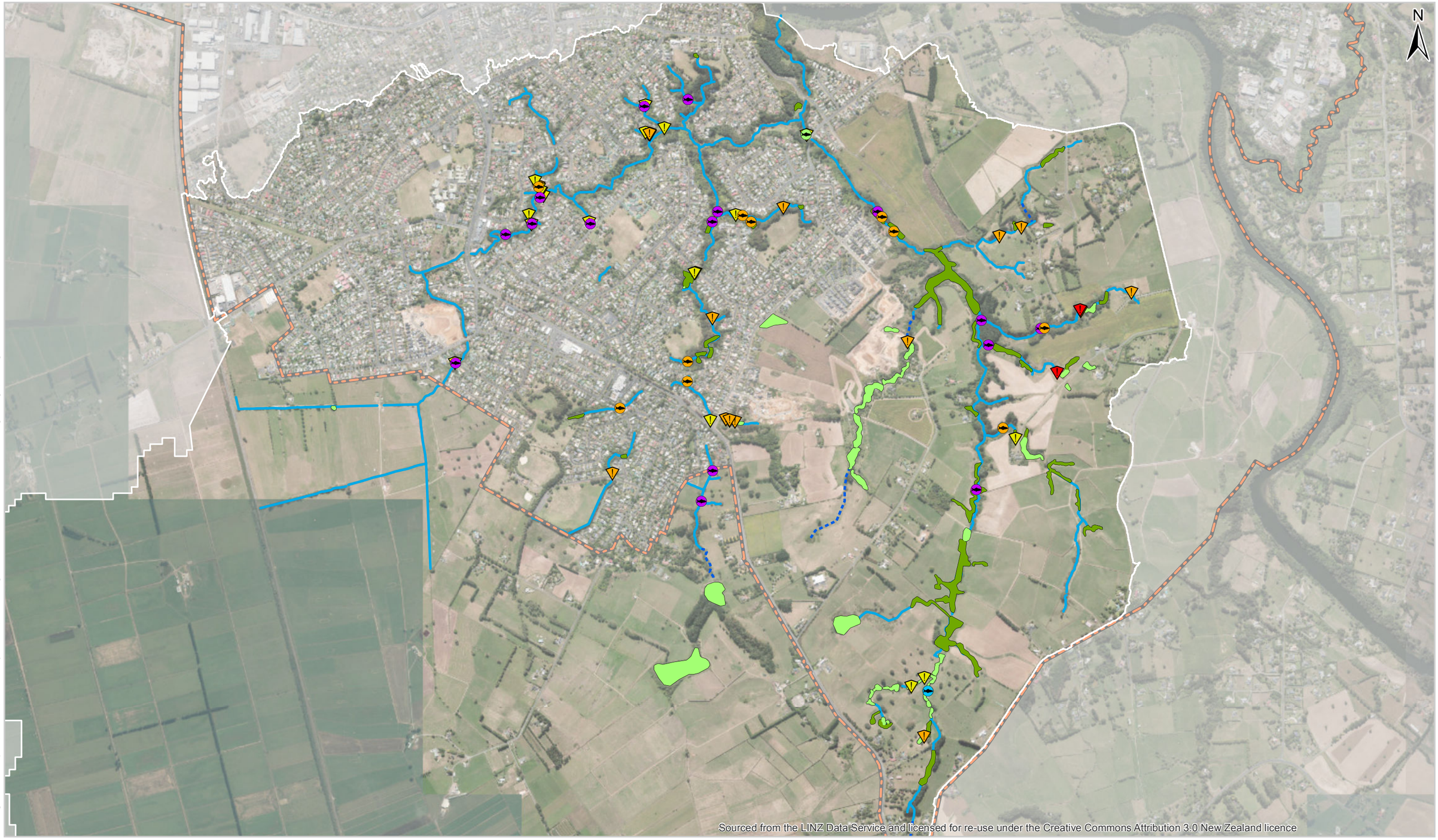
Drawn CU

Approved ER

Map 4 – Fish Barriers and Fish Survey

MAP 4 - FISH PASSAGE BARRIERS AND FISH SURVEY RESULTS

MORPHUM ENVIRONMENTAL LTD



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Fish Survey
- Anguilliform
- Climber
- Swimmer
- Exotic

Fish Barrier
- Anguilliforms
- Climbers
- Swimmers

Wetland Type
- Natural
- Artifical

- Ecoline
- Watercourse - not assessed
- Stormwater Catchments
- HCC Boundary

Client HAMILTON CITY COUNCIL
Project **Mangakotukutuku WAR**

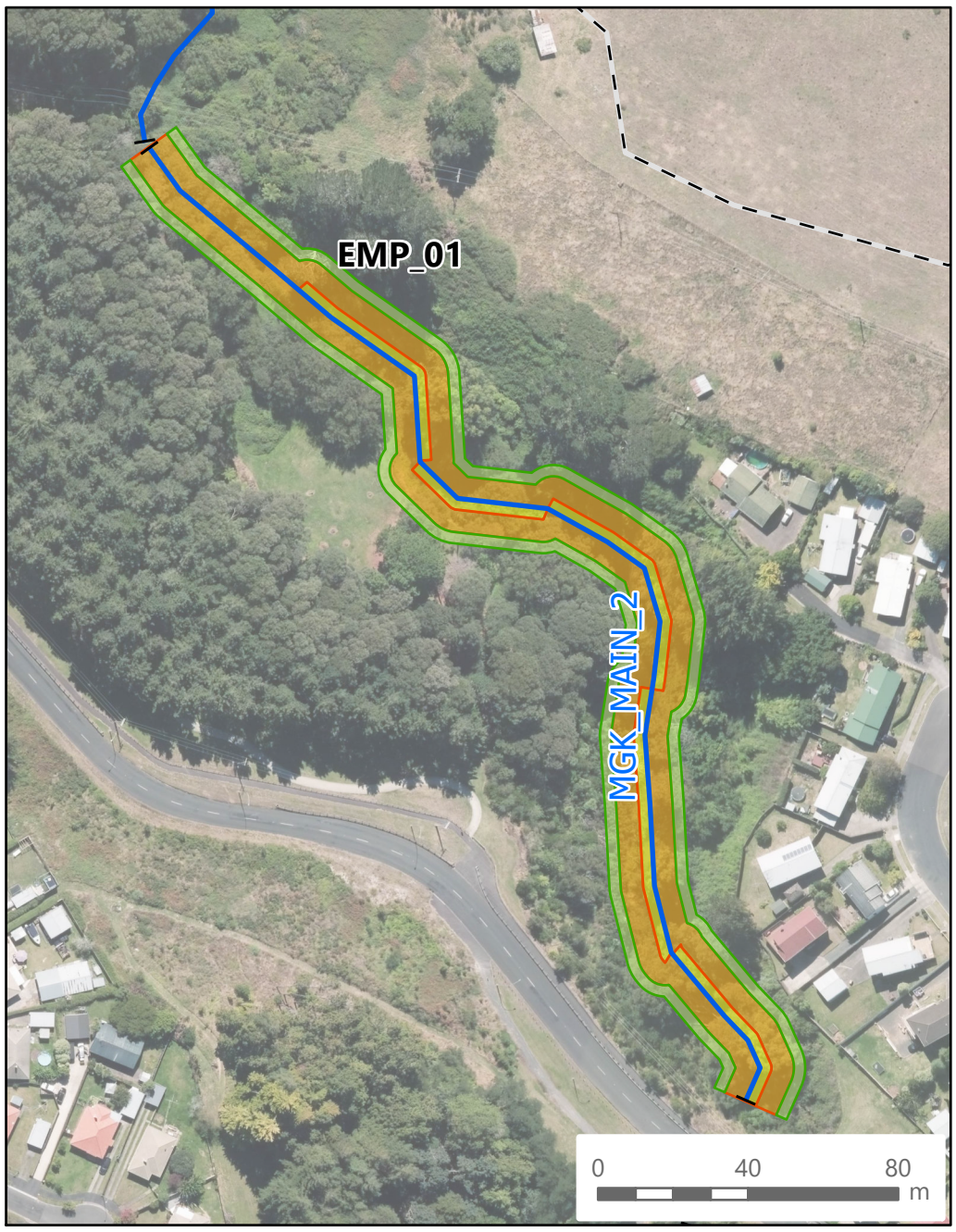
0 750 1,500 m

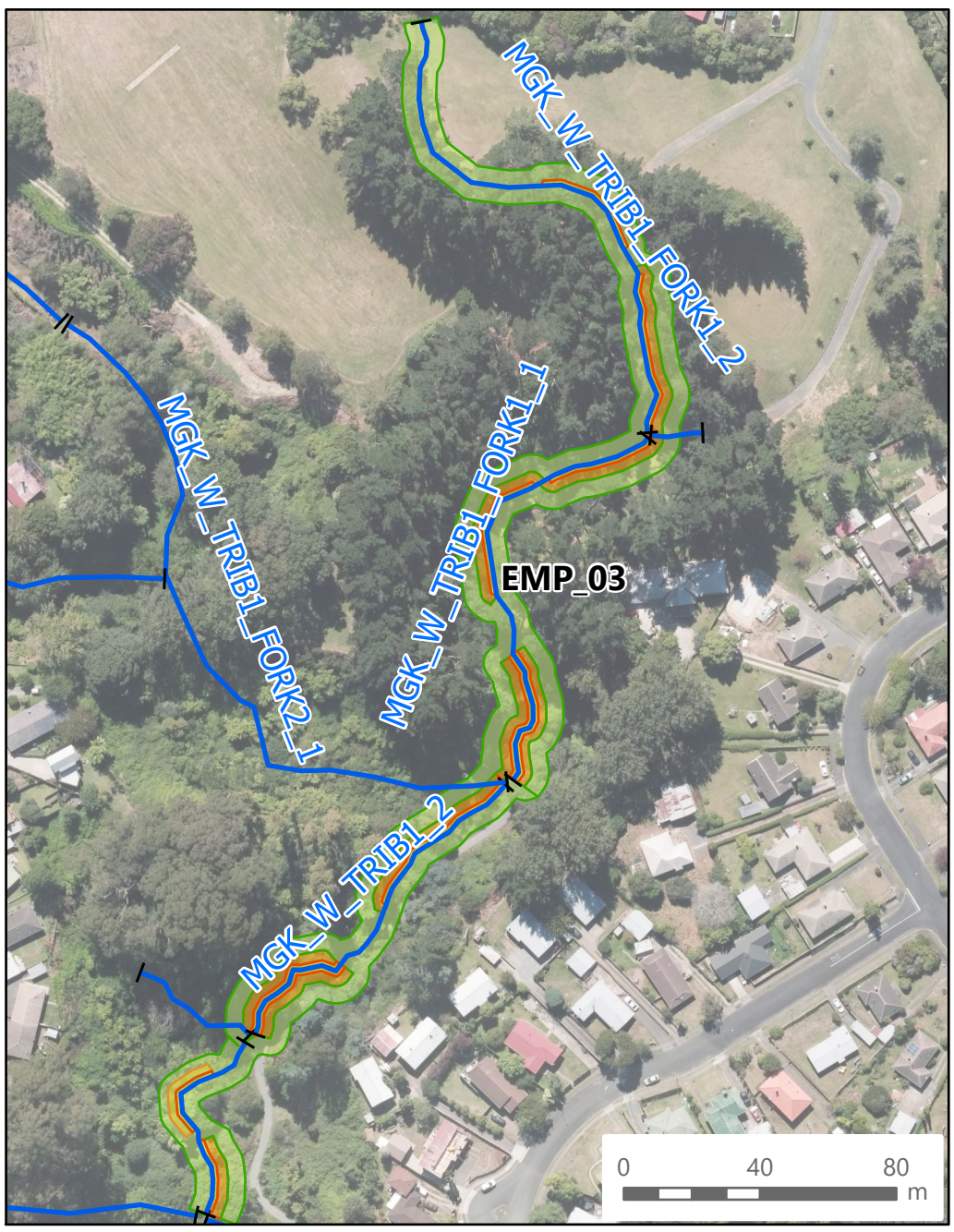
Project no. P01236
Date 16 Jun 2017

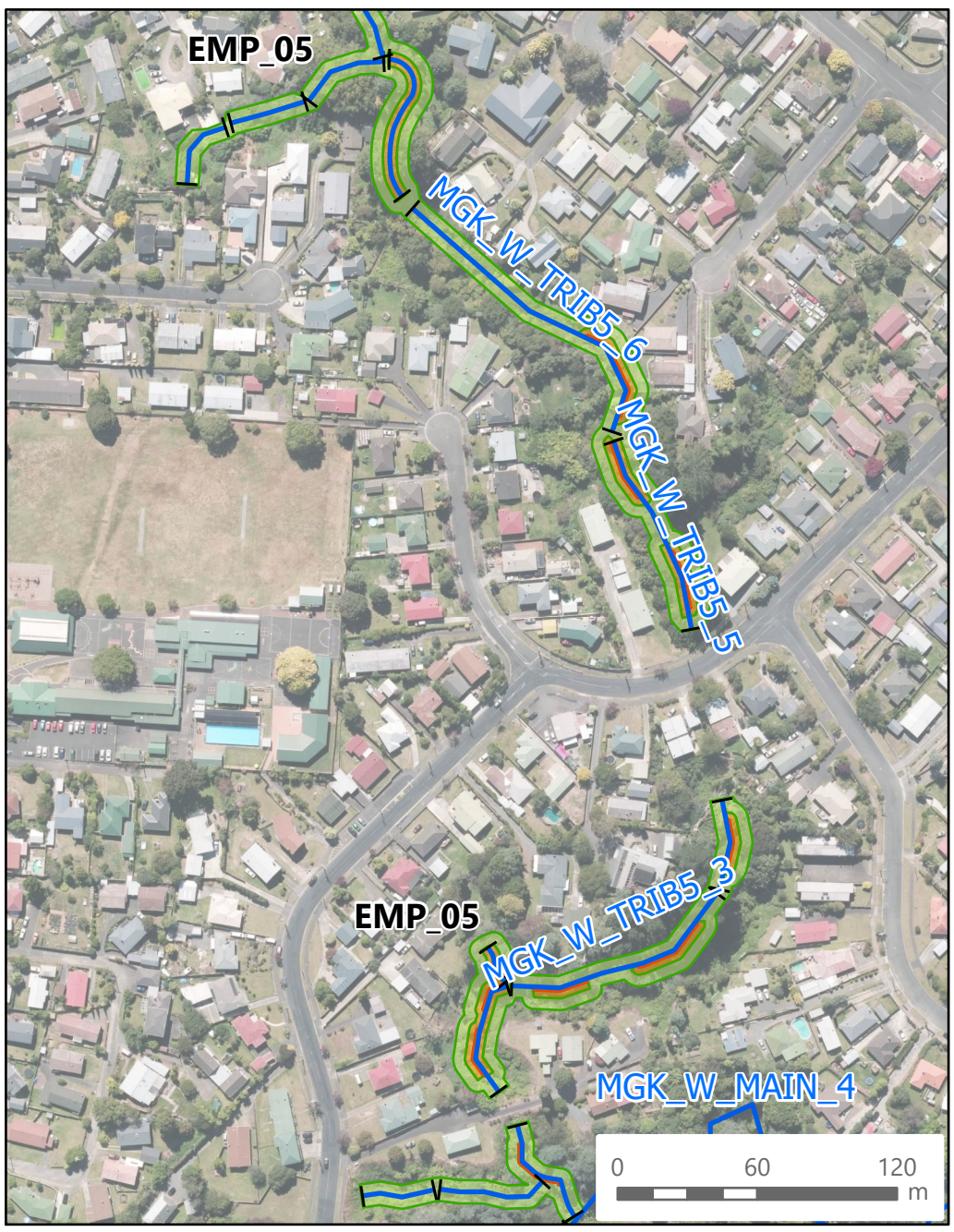
Drawn CU
Approved ER

Map 5 – Erosion Mitigation Projects

MANGAKOTUKUTUKU - EROSION REMEDIATION PROJECTS







Erosion Mitigation Works

- Bank Batter
- Erosion Planting
- Grade Control
- Retaining
- Toe Protection

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

Project no. P01236

Date 7 Jan 2019

Drawn SM

Approved DY

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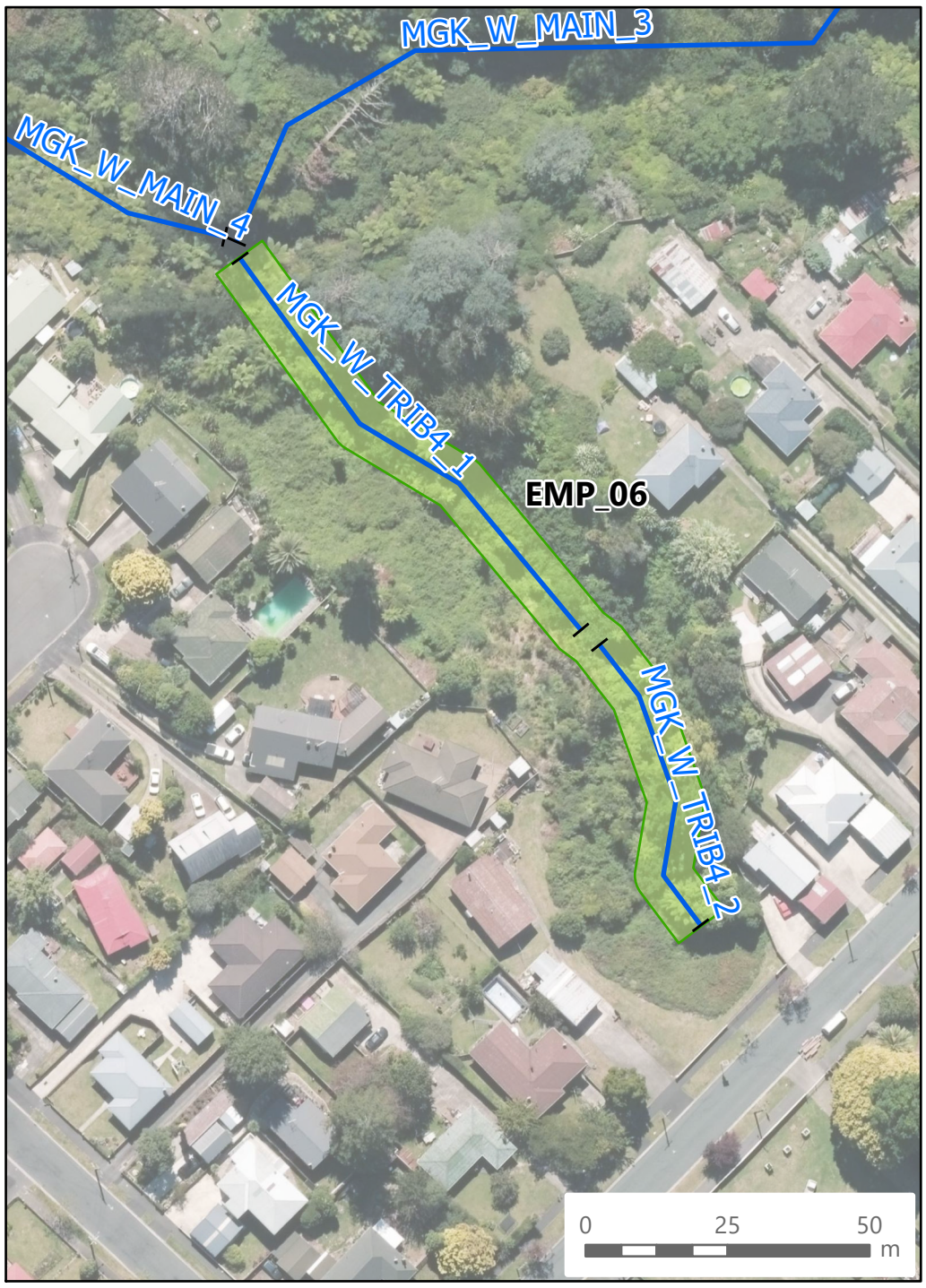
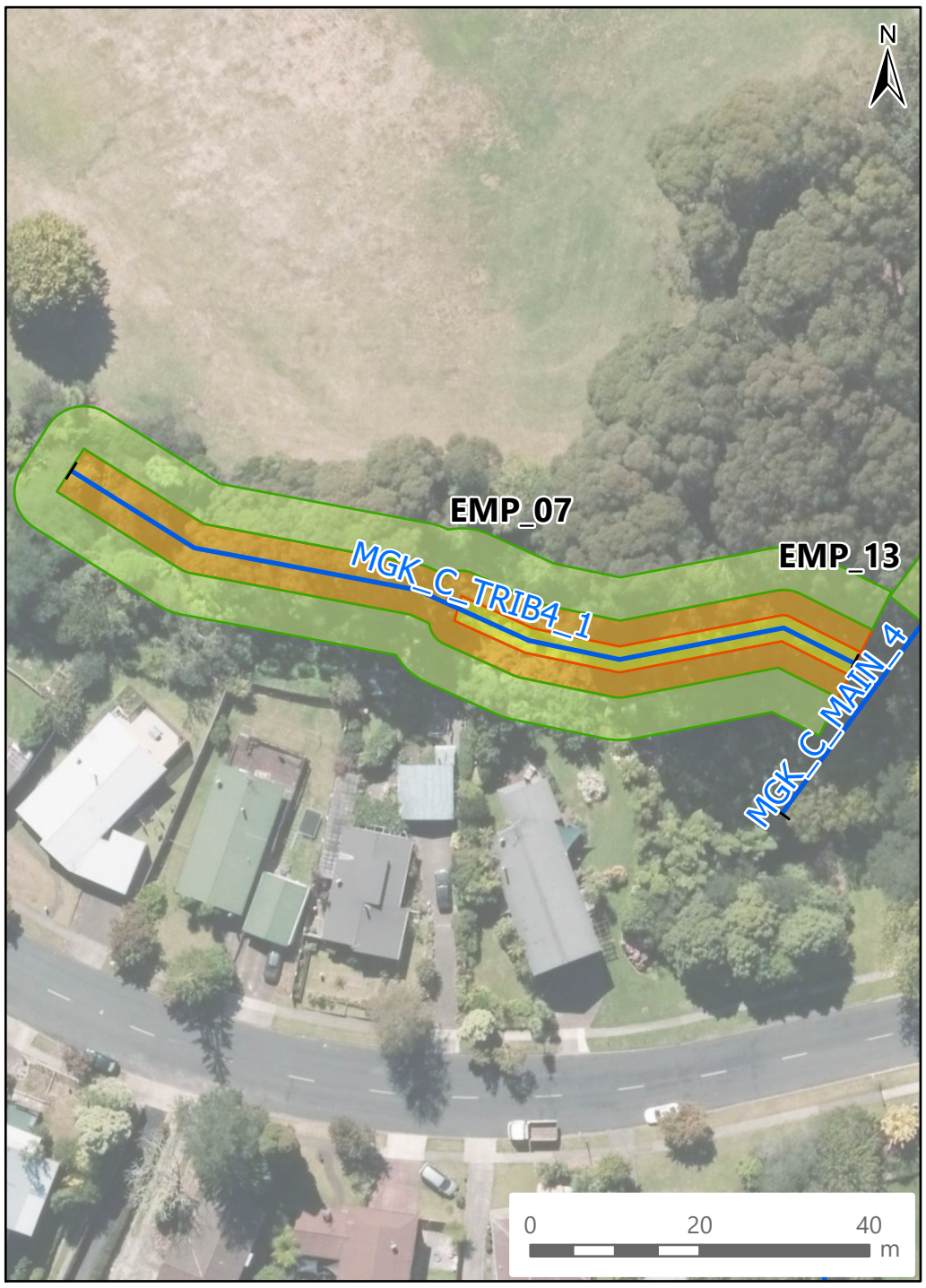
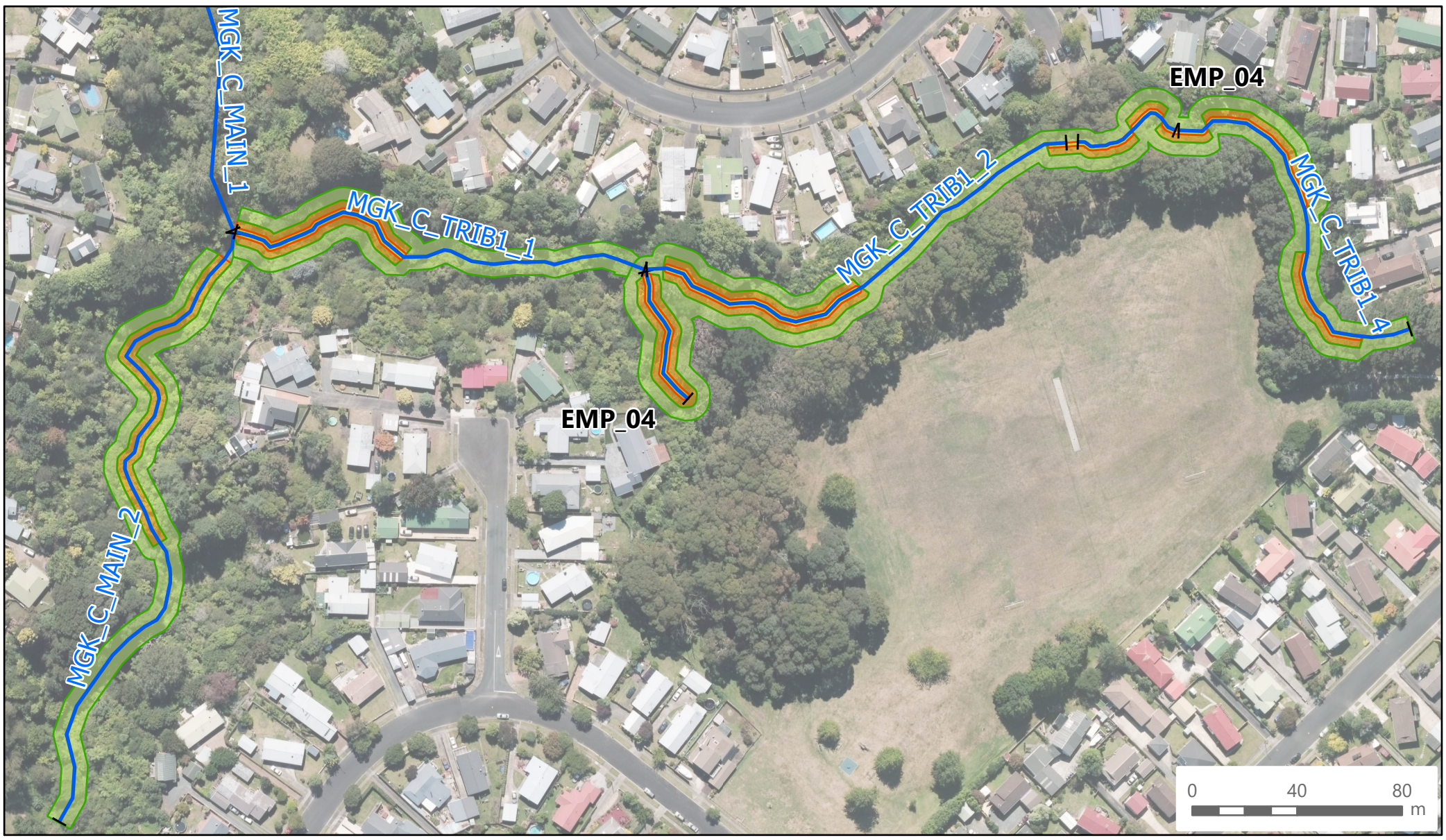
MANGAKOTUKUTUKU - EROSION REMEDIATION PROJECTS







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Erosion Mitigation Works

- Bank Batter
- Erosion Planting
- Grade Control
- Retaining
- Toe Protection

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

Project no. P01236

Date 7 Jan 2019

Drawn SM

Approved DY

MANGAKOTUKUTUKU - EROSION REMEDIATION PROJECTS

Erosion Mitigation Works

- Bank Batter
- Erosion Planting
- Grade Control
- Retaining
- Toe Protection

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

Project no. P01236

Date 7 Jan 2019

Drawn SM

Approved DY

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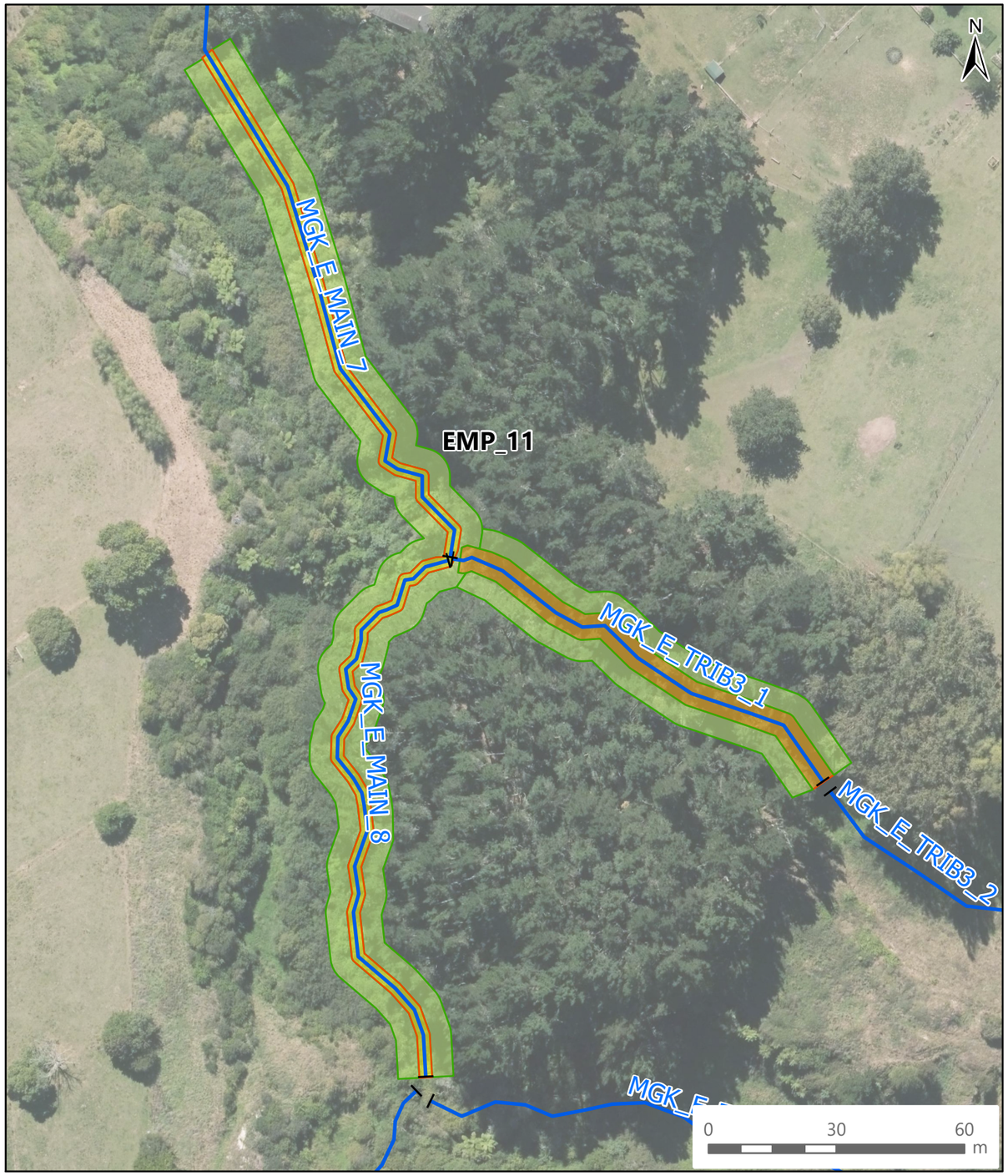
MANGAKOTUKUTUKU - EROSION REMEDIATION PROJECTS



Erosion Mitigation Works

- Bank Batter
- Erosion Planting
- Grade Control
- Retaining
- Toe Protection

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

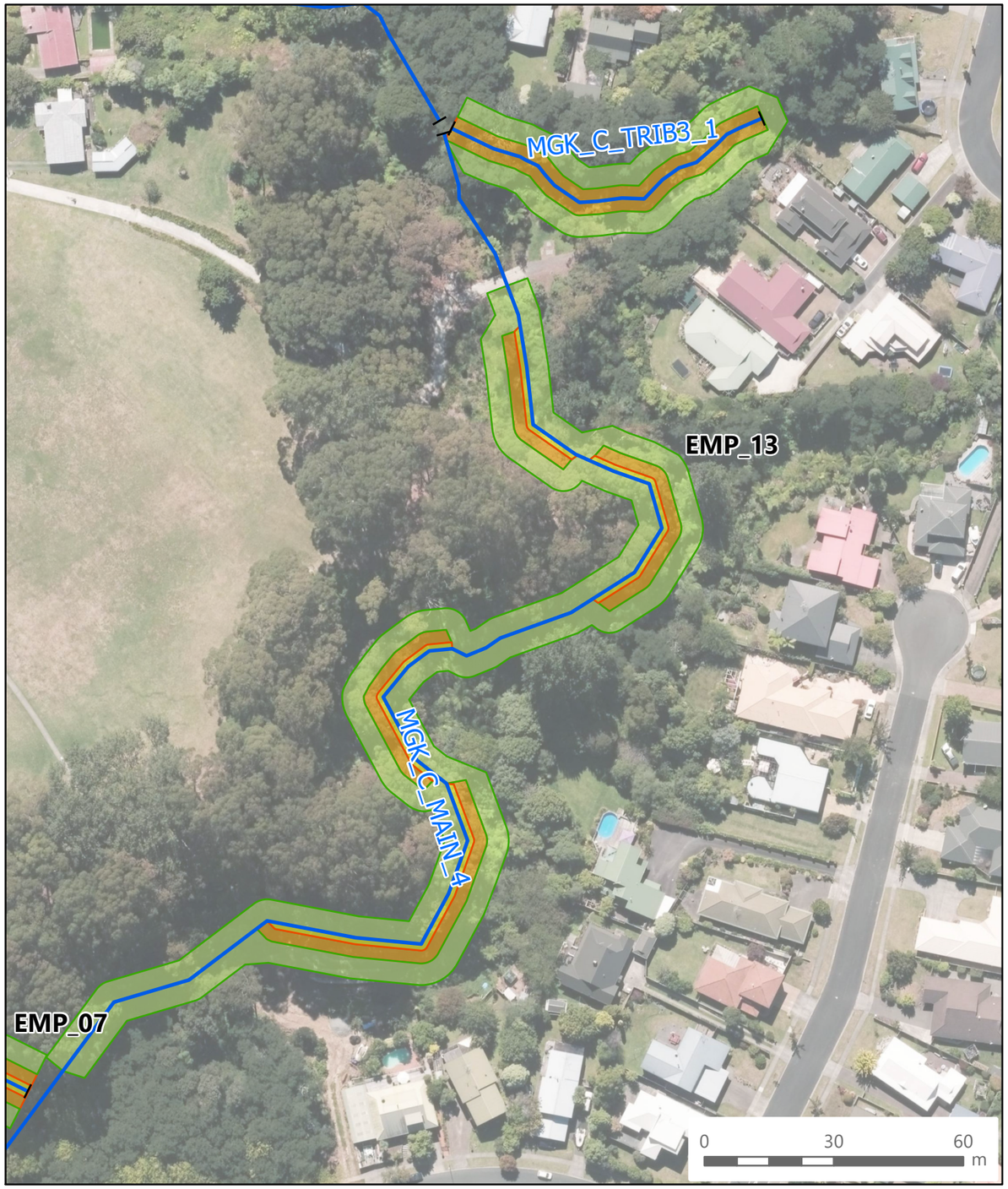
Project no. P01236

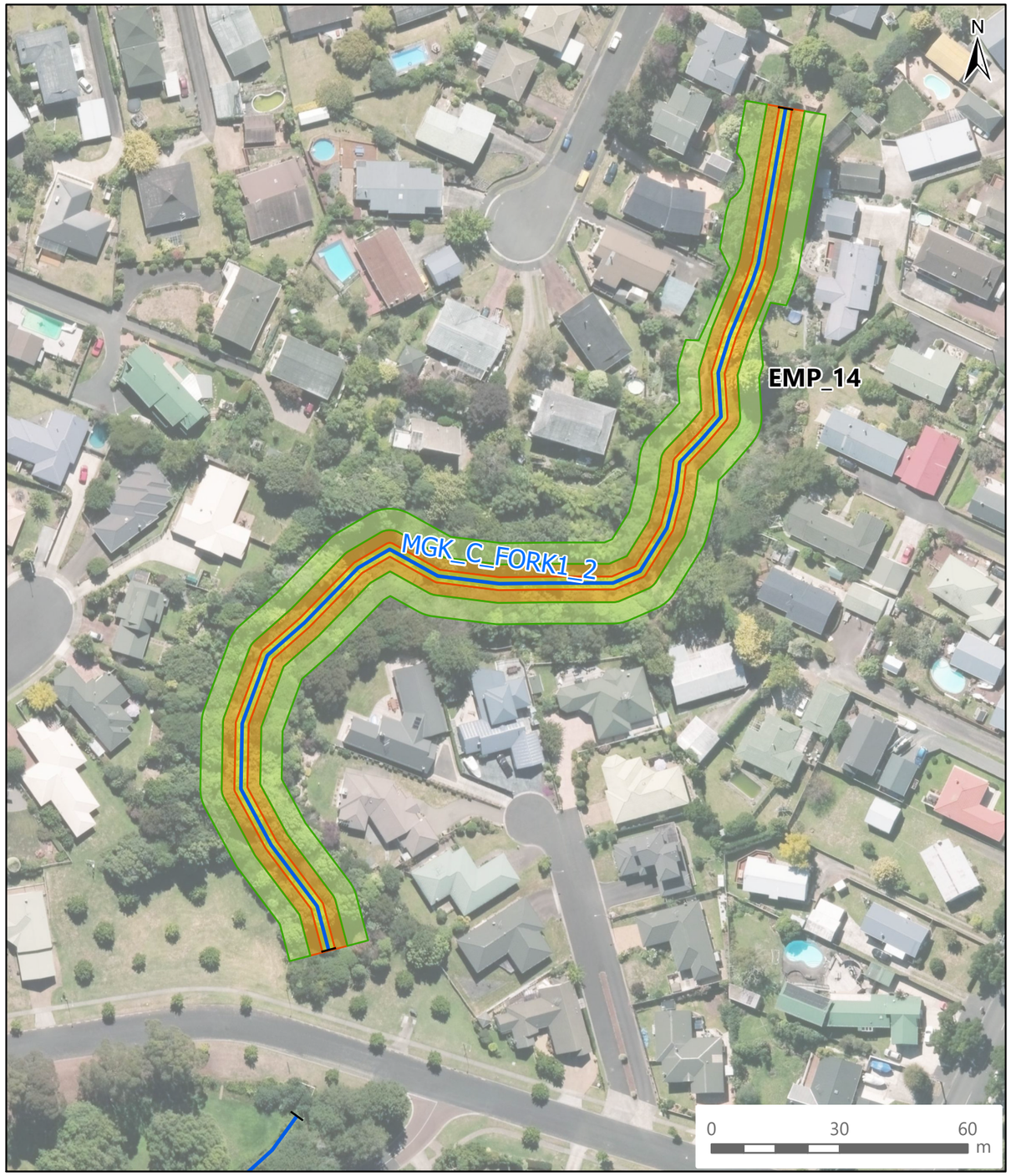
Date 7 Jan 2019

Drawn SM

Approved DY

MANGAKOTUKUTUKU - EROSION REMEDIATION PROJECTS





Erosion Mitigation Works

- Bank Batter
- Erosion Planting
- Toe Protection

- Ecoline
- ICMP Catchment Boundary
- ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

Project no. P01236

Date 7 Jan 2019

Drawn SM

Approved DY

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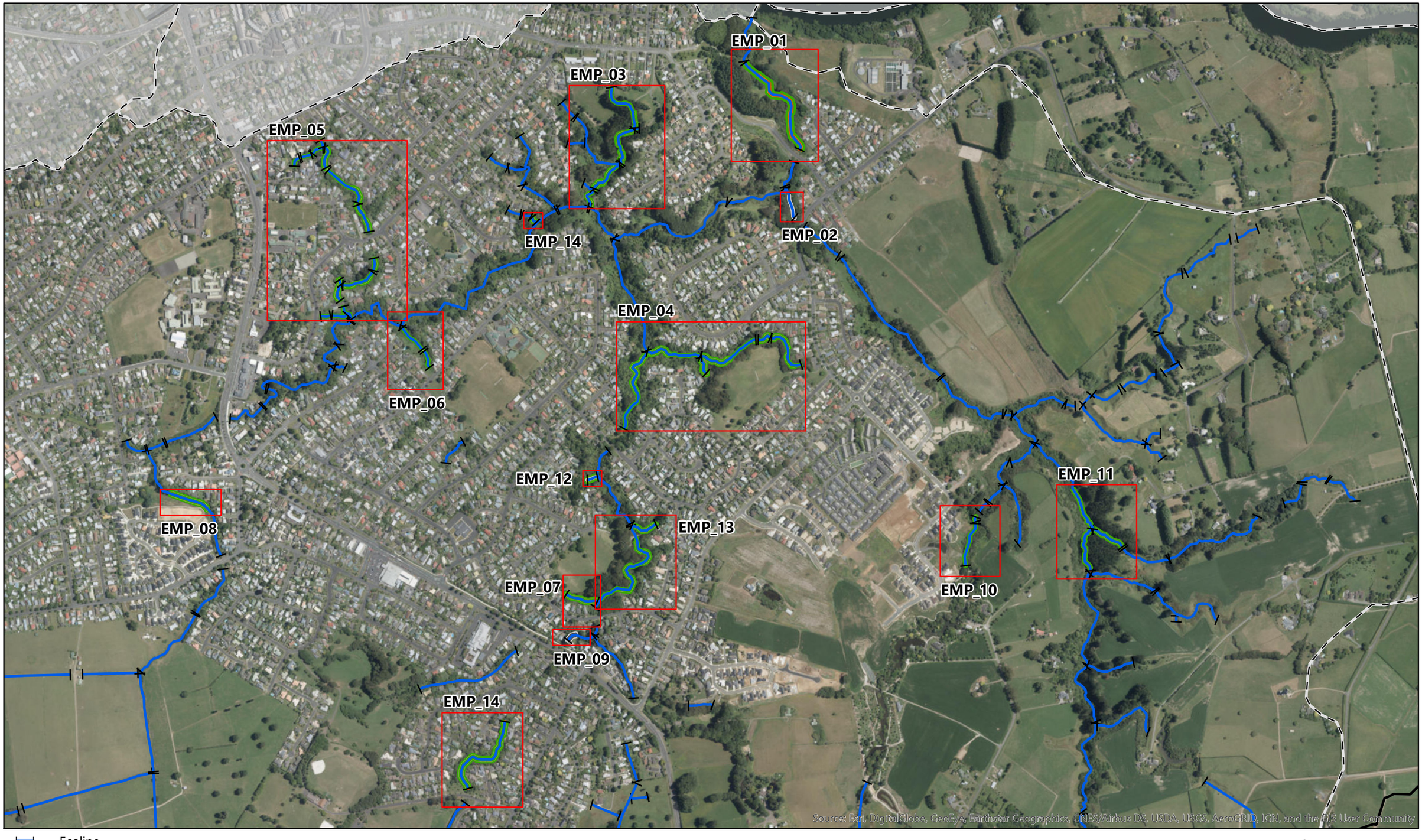
MANGAKOTUKUTUKU - EROSION REMEDIATION PROJECT OVERVIEW



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Ecoline

ICMP Catchment Boundary

ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

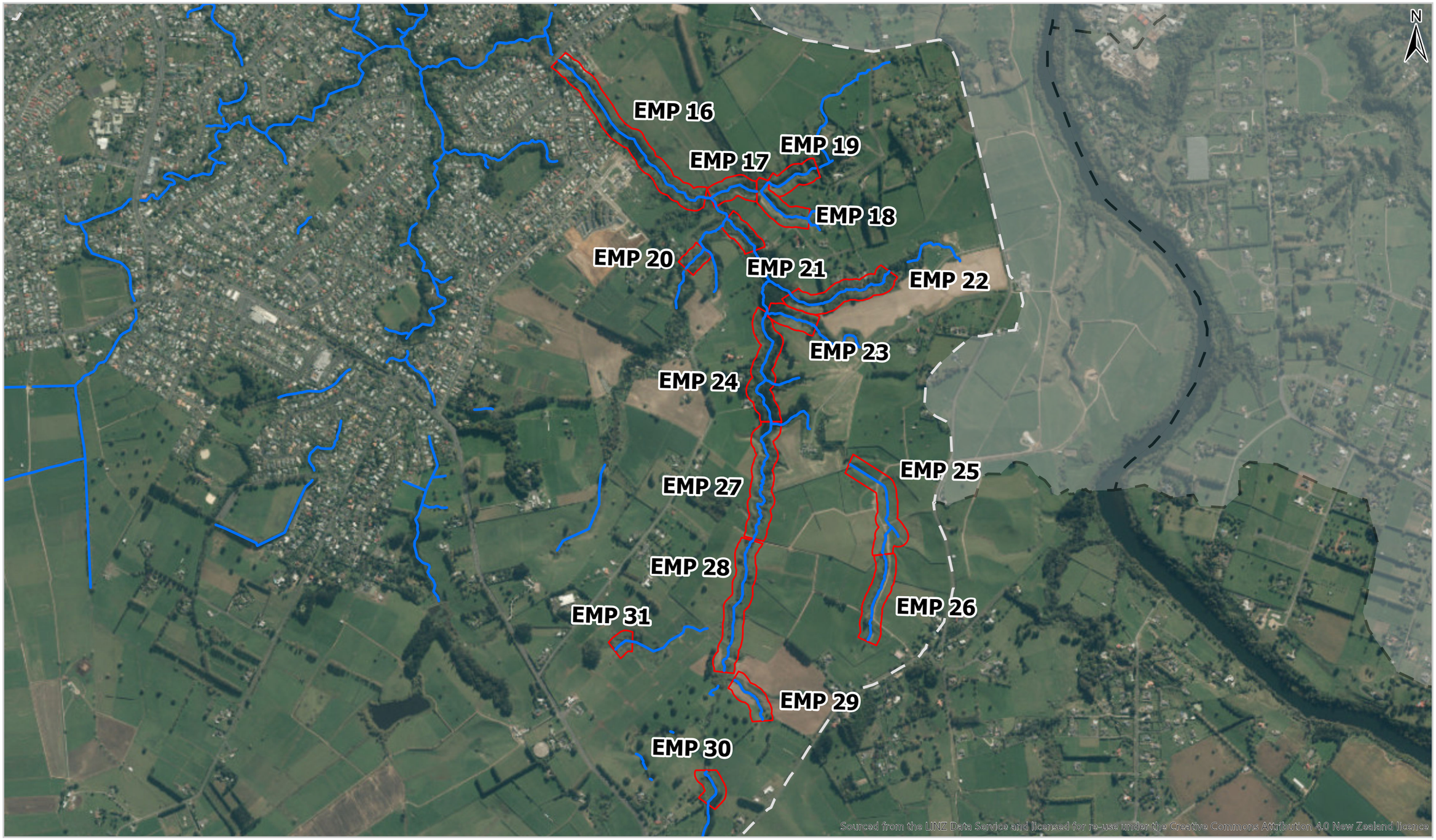
Project no. P01236

Date 7 Jan 2019

Drawn SM

Approved DY

MANGAKOTUKUTUKU - FUTURE EROSION REMEDIATION PROJECT



Ecoline

ICMP Catchment Boundary

ICMP Subcatchments

EMP

Client HAMILTON CITY COUNCIL

Project **FUTURE EROSION REMEDIATION PROJECT**

0 480 960 m

Project no. P01236

Date 31 Oct 2019

Drawn JC

Approved JM

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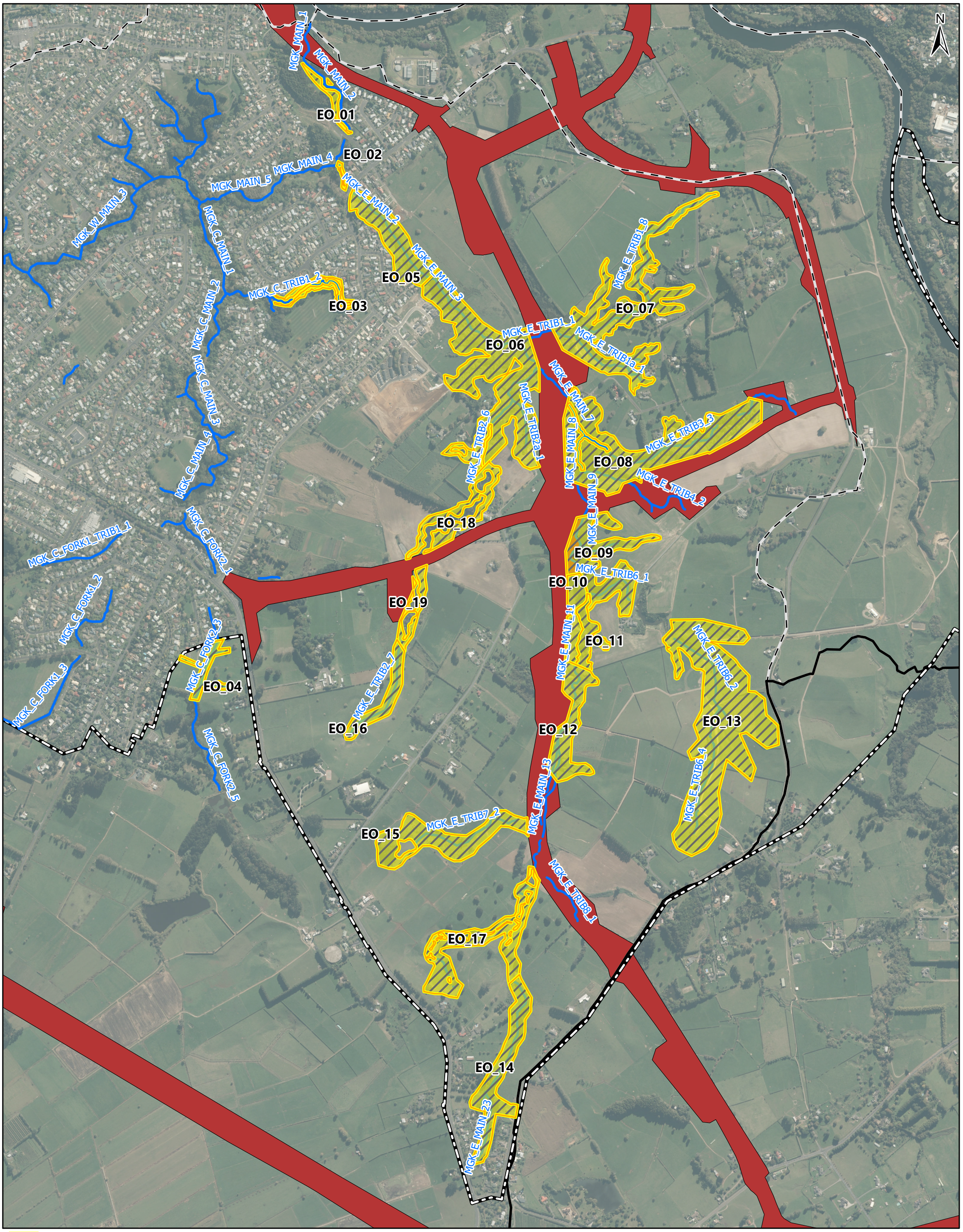
Map 6 – Enhancement Opportunity Projects

MANGAKOTUKUTUKU - STREAM ENHANCEMENT

MORPHUM ENVIRONMENTAL LTD



Enhancement Opportunities
Ecoline
Southern Links Designation
Hamilton City Boundary
ICMP Catchment Boundary
ICMP Subcatchments

Client HAMILTON CITY COUNCIL

PROJECT **MANGAKOTUKUTUKU WAR**

0 500 1,000 m

Project no. P01236
Date 7 Jan 2019

Drawn SM
Approved DY

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Appendix 2 Cost and Unit Rates for Mitigation Options

Mitigation	Unit	Cost	Assumptions and exclusions
Planting of Banks and Floodplains	m^2	$35	Includes boom spray of glyphosate single application; Planting at up to 4 plants per m2. *Carex, Juncus*, toetoe, flax and cabbage tree; Plant grade PB3s; Assumes team of 6 planting 350 plants each per day; Cost includes vegetation removal, planting, weeding and maintenance for 5 years.
Newbury Rock Riffles as Grade Control	m^2	$950	Import and place rock riffles. Weirs to be 400-500 mm boulders, riffles to be D_{50}=300 mm well graded angular rip rap in combination with 5-50mm railway ballast, approximately 20m^3 of rip rap per riffle. 50mm bedding layer of GAP30 installed over existing ground surface. Crushed aggregate D_{50}=50 mm to be installed to fill gaps around rip rap.
Bank batter	m^3	$70	$50/m^3$ for excavation; $20/m^3$ for haulage away from site and disposal to clean fill; Does not include setting up diversions/erosion and sediment control; Assumes 45° banks from toe of existing bank, does not include the excavation required to install the rip rap. The rip rap volume may need to be excavated also for installation of the rip rap. This could be avoided by placing the rip rap directly on the cut bank. Rip rap may not be required at all sites of bank batter but has been used here to allow for the cost of stabilisation. Determination of the best stabilisation material will be decided during concept design or detailed design. Note: Any topsoil removed as part of the excavation will be re-spread. No importation of topsoil has been allowed for due to potentially changing the planting environment
Rip rap for banks	m^3	$600	D_{50} = 300mm
Coir matting	m^2	$10	
Keystone Boulders	m^3	$1,500	600 mm boulders placed within a 400 mm deep trench
Fencing	m	$7.50	7 wire fencing with 5 m posting

Appendix 3 Erosion Mitigation Projects Preparation and Planning Breakdown Cost

Planning and preparation costs breakdown ($ rounded to nearest $000)

Project ID	Physical Works Total	Design and Feasibility (10%)	Resource Consent (3%)	Defects and Liability (10%)	Sub-Total	Total including Contingency (20%)
EMP_01	737,000	74,000	22,000	74,000	907,000	1,088,000
EMP_02	105,000	11,000	3,000	11,000	130,000	156,000
EMP_03	394,000	39,000	12,000	39,000	484,000	581,000
EMP_04	703,000	70,000	21,000	70,000	864,000	1,037,000
EMP_05	428,000	43,000	13,000	43,000	527,000	632,000
EMP_06	52,000	5,000	2,000	5,000	64,000	77,000
EMP_07	242,000	24,000	7,000	24,000	297,000	356,000
EMP_08	231,000	23,000	7,000	23,000	284,000	341,000
EMP_09	113,000	11,000	3,000	11,000	138,000	166,000
EMP_10	56,000	6,000	2,000	6,000	70,000	84,000
EMP_11	296,000	30,000	9,000	30,000	365,000	438,000
EMP_12	112,000	11,000	3,000	11,000	137,000	164,000
EMP_13	598,000	60,000	18,000	60,000	736,000	883,000
EMP_14	587,000	59,000	18,000	59,000	723,000	868,000
EMP_15	17,000	2,000	1,000	2,000	22,000	26,000

Sub Total	**$ 4,671,000**					**$ 6,897,000**
EMP_16	788,000	970,000	1,164,000	1,164,000	3,377,000	3,377,000
EMP_17	175,000	216,000	259,000	259,000	752,000	752,000
EMP_18	348,000	428,000	514,000	514,000	1,491,000	1,491,000
EMP_19	79,000	97,000	116,000	116,000	337,000	337,000
EMP_20	129,000	159,000	191,000	191,000	554,000	554,000
EMP_21	130,000	160,000	192,000	192,000	557,000	557,000
EMP_22	195,000	241,000	289,000	289,000	839,000	839,000
EMP_23	145,000	179,000	215,000	215,000	624,000	624,000
EMP_24	362,000	445,000	534,000	534,000	1,549,000	1,549,000
EMP_25	269,000	331,000	397,000	397,000	1,152,000	1,152,000
EMP_26	103,000	126,000	151,000	151,000	438,000	438,000
EMP_27	417,000	514,000	617,000	617,000	1,790,000	1,790,000
EMP_28	443,000	544,000	653,000	653,000	1,894,000	1,894,000
EMP_29	98,000	121,000	145,000	145,000	421,000	421,000
EMP_30	72,000	88,000	106,000	106,000	307,000	307,000
EMP_31	63,000	77,000	92,000	92,000	267,000	267,000
Subtotal	**$ 3,816,000**					**$ 5,635,000**
Total	**$ 8,487,000**					**$ 12,532,000**