Assessment of Ecological Effects – Freshwater Ecology

December 2017

River Lake Limited

Technical Report 7b

NZ TRANSPORT AGENCY WAKA KOTAHI | Mt Messenger Bypass

New Zealand Government

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Contents

Glossary

Term	Meaning
AEE	Assessment of Effects on the Environment Report
AWA	Additional (Ancillary) works area
DOC	Department of Conservation
DOC Assessment Guidelines	DOC's *Guidelines for Assessing Ecological Values*, developed by Davis *et al.* in 2016
DTM	Digital Terrain Model
Eastern Ngāti Tama forest block	The area of land largely owned by Ngāti Tama located east of existing SH3, including the Project footprint, approximately 3,098ha in size
EcIA guidelines	Ecological Impact Assessment guidelines
ECR	Environmental Compensation Ratio
EIANZ	Environment Institute of Australia and New Zealand
ELMP	Ecology and Landscape Management Plan
EPT	Ephemeroptera-Plecoptera-Trichoptera taxa
MCI	Macroinvertebrate Community Index
North Taranaki Ecological District	Part of the Taranaki Ecological Region, encompasses approximately 259,750 ha, including the Project footprint
NZFFD	New Zealand Freshwater Fish Database
Parininihi	The area spanning the Waipingao Stream catchment located to the west of existing SH3, approximately 1,332ha in size
Pest Management Area	Area of land proposed to be actively managed for pests, across a number of parcels of land
Project	The Mt Messenger Bypass project

Term	Meaning
Project footprint	The Project footprint includes the road footprint (i.e. the road and its anticipated batters and cuts, spoil disposal sites, haul roads and stormwater ponds), and includes the Additional Works Area (AWA) and 5m edge effects parcel.
QMCI	Quantitative Macroinvertebrate Community Index
RMA	Resource Management Act 1991
RTC	Residual trap catch
SEV	Stream Ecological Valuation
SH3	State Highway 3
Transport Agency	New Zealand Transport Agency
TRC	Taranaki Regional Council
Wider Project area	An area approximately 4,430ha in size which encompasses Parininihi and the Ngāti Tama Eastern forest block, and includes the Project footprint.

Executive Summary

The NZ Transport Agency is to develop a new section of SH3, north of New Plymouth, to bypass the existing steep, narrow and winding section of highway at Mt Messenger. The Project comprises a new section of two lane highway, some 6km in length, located to the east of the existing SH3 alignment.

The overarching ecological aim for the project is to ensure no net loss of biodiversity values, or to achieve a net benefit of biodiversity values, within the short- to medium-term.

This report assesses the effects of construction and operation of the Project on the aquatic ecology of streams. The Project traverses two river catchments; the Mangapepeke Stream, which flows north to the Tongaporutu River, and the Mimi River, which flows south.

Field surveys were undertaken in early June and August 2017. These surveys visited all affected sites where access was possible. Detailed survey methods were undertaken at representative sites; this included a habitat survey at 15 sites, Stream Ecological Valuation survey at 11 sites, collection of aquatic macroinvertebrate samples at the same 11 sites and fish surveys at six sites.

The Mt Messenger area consists of high quality habitat for indigenous terrestrial and aquatic flora and fauna. The geology is dominated by papa mudstone; this has a considerable influence on stream substrate and sediment. Both catchments are predominantly covered in indigenous forest but the valleys through which the streams meander is mainly pasture and grazed wetland. The aquatic macroinvertebrate community indicated 'excellent' water quality/habitat near the headwaters. In the Mangapepeke Stream MCI scores reduced downstream to values indicative of 'fair' to 'good' conditions, but in the main stem of the Mimi River the scores remained high.

Both streams had a high diversity of fish, with Fish IBI scores indicating 'excellent' diversity in lowland sections and 'good' diversity in steeper sections. Fish caught included: inanga, longfin eel, giant kōkopu, banded kōkopu, redfin bully, common bully, kōura and kākahi.

The potential effects of the Project on streams include short term effects related to the construction phase and long term effects that continue well after the construction phase. Potential short term effects include sedimentation, direct removal of fish from the stream, short-term loss of fish passage in some areas and short-term loss of stream habitat from temporary culverts. Potential long-term effects include reduced fish passage, loss of stream ecological functions and habitat, and potential effects of road stormwater on stream hydrology and water quality.

The potential effects on streams during the construction period can be minimised and mitigated by implementing good practice with respect to erosion and sediment control, fish recovery, vegetation clearance, water takes and undertaking monitoring during the construction period. Similarly, many of the long-term effects from the road footprint can be minimised and mitigated by good culvert design to ensure fish passage, stormwater management, and design of stream diversions.

Nevertheless, the piping and diversion of streams required by the Project will affect 3,470m of stream and cause, after mitigation, considerable loss of stream values; this residual effect will be addressed by implementing offset compensation.

The Stream Ecological Valuation (SEV) method was used calculate the amount of offset required for the loss of stream habitat. To achieve 'no net loss' restoration work will be required along 8,724m^2 of stream habitat.

Overall, the effects of the Project on freshwater ecology can be appropriately managed and mitigated, and the residual loss of habitat can be adequately offset to result in 'no net loss' of stream values

1 Introduction

1.1 Background

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's Mt Messenger bypass Project (the Project). Its purpose is to inform the Assessment of Effects on the Environment Report (AEE) and to support the resource consent applications and a Notices of Requirement to alter the existing State Highway designation, which are required to enable the Project to proceed.

This report assesses the effects of construction and operation of the Project on aquatic ecology. The purpose of this report is to:

a Identify and describe the existing freshwater environment and ecology;

b Describe the potential effects on freshwater ecology arising from construction and operation of the Project;

c Recommend measures as appropriate to avoid or mitigate potential effects on freshwater ecology (eg management plans); and

d Present an overall conclusion of the level of potential effects of the Project on freshwater ecology after recommended measures are implemented.

1.2 Project description

The Project involves the construction and ongoing operation of a new section of State Highway 3 (SH3), generally between Uruti and Ahititi to the north of New Plymouth. This new section of SH3 will bypass the existing steep, narrow and winding section of highway at Mt Messenger. The Project comprises a new section of two lane highway, approximately 6 km in length, located to the east of the existing SH3 alignment.

The Project is intended to enhance the safety, resilience and journey time reliability of travel on SH3 and contribute to enhanced local and regional economic growth and productivity for people and freight.

A full description of the Project including its design, construction and operation is provided in the Assessment of Effects on the Environment Report, contained in Volume 1: AEE, and is shown on the Drawings in Volume 2: Drawing Set.

The overarching ecological aim for the project is to ensure no net loss of biodiversity values, or to achieve a net benefit of biodiversity values, within the short- to medium-term.

The Project design includes many features to avoid, mitigate and offset effects on the environment. At a high level, this includes bridging some areas of high value swamp forest, choosing alignments that minimise impacts on the valley floor, and choosing a route that avoids impacts on the near pristine Waipingao Valley (west of the current SH3) and minimises risks to the Parininihi Marine Reserve.

Some other design options were reject because of practical constraints and the need to minimise multiple effects. For example, multi-barrel piped culverts are used at site Ea10 rather than an arch culvert because the height of the road does not allow sufficient fill to cover an arch culvert, and lifting the road at this point would increase its footprint.

2 Method

2.1 Introduction

A desktop assessment was undertaken to review available information and data relating to the freshwater ecology of the Project footprint and the surrounding area. This included:

- Review of NZ Freshwater Fish Database (NZFFD);
- Discussions with Department of Conservation (DoC) about unpublished biological data; and
- Discussions with Taranaki Regional Council regarding water quality or biological data.

In addition to the desktop assessment, field surveys of waterways impacted by the Project were undertaken in early June 2017 and early August 2017.

Previous field surveys were also carried out in February 2017 to the west of the existing SH3, to assess the effects of different route options (e.g. MC23) (Hamill 2017). The survey used the same field method as those in June and August 2017. The streams surveyed in February will not be affected by the Project but the survey nonetheless provides useful contextual information on streams in the wider area, some of which may be suitable for restoration as part of the Project's offset package (described in further detail in the Assessment of Ecological Effect – Ecological Mitigation and Offset (Technical Report 7h, Volume 3 of the AEE).

2.2 Sample locations

The proposed route is located to the east of the existing SH3 and traverses two river catchments. On the north side of Mt Messenger, the waterways drain to the Mangapepeke Stream, itself a tributary to the Mangaongaonga Stream and the Tongaporutu River which enters the coast at Tongaporutu. On the south side of Mt Messenger, the waterways drain to the Mimi River, which flows south-west to enter the coast between Waiiti and Urenui (Figure 2.1).

All waterways potentially affected by the alignment were identified using aerial photographs and a 3D Digital Terrain Model of the rivers. All sites were visited and measurements made except for some tributaries entering the lower Mangapepeke Stream where access was not granted by the land owner (ie sites Ea3, Ea4, Ea5, Ea6, Ea7, Ea8 and Ea9). In some cases, the rugged terrain and waterfalls restricted access to stream sections downstream of the actual alignment (ie site Ea14 and Ea15).

A habitat survey was undertaken at 15 sites, and Stream Ecological Valuation (SEV) method was applied at 11 sites, aquatic macroinvertebrate samples collected at the same 11 sites and a fish survey was done at six sites (see Table 2.1). The SEV surveys occurred at representative sites with a partial bias towards larger waterways. Where a full SEV survey was not undertaken a SEV score was assigned based on the results from other sites with similar stream habitat.

Some of the sites surveyed were downstream of the actual alignment but potentially affected by sedimentation (eg site Ea25 in the kahikatea (*Dacrycarpus dacrydioides*) swamp forest); other sites surveyed were on sections of stream with potential for restoration as part of a compensation package (eg sites Ea26, Ea27 and Ea28 in the Mimi catchment, sites E2 and E4 in the Mangapepeke catchment). There are many potential stream sections that could be restored as part of an offset compensation package, but the necessary property access rights would need to be obtained. [1]

The location of sites surveyed along the proposed route are shown in Figure 3.1a to 3.1c and described in Table 2.1.

[1] In this report the term 'offset compensation' is used interchangeably with the term 'biodiversity offset'. The term 'compensation' is included to reflect the language used in the SEV method.

Table 2.1– Location of waterways potentially affected by the Project (culverts, swales, stream diversion) and stream surveys. Sorted north to south. Shaded sites were not visited.

Site	Catchment	latitude	longitude	catchment area (ha)	ID culvert / diverson	Chainage	Length of culvert / diversion	survey method
Ea1	Mangapepeke trib	38°52'10.82"	174°35'54.68"	3.82	1	250	24	
Ea2	Mangapepeke trib	38°52'14.87"	174°35'54.40"	1.80	2	300	26	
E1	Mangapepeke	38°52'23.99"	174°35'58.48"	328				H, F
Ea3	Mangapepeke trib	38°52'23.89"	174°36'0.88"	6.3	3	570	67	
Ea4	Mangapepeke trib	38°52'26.85"	174°36'3.21"	1.8	4	750	81	
Ea5	Mangapepeke trib	38°52'30.51"	174°36'4.84"	4.2	5	870	87	
E2	Mangapepeke	38°52'34.31"	174°36'2.21"	306				SEV, H
Ea6	Mangapepeke trib	38°52'34.67"	174°36'5.34"	4.4	swale			
Ea7	Mangapepeke trib	38°52'44.11"	174°36'8.30"	6.8	6	1310	27	
E2a	Mangapepeke	38°52'46.49"	174°36'9.19"	248				H
Ea8	Mangapepeke trib	38°52'49.47"	174°36'14.05"	5.8	7	1500	36	
Ea9	Mangapepeke trib	38°52'53.77"	174°36'17.59"	7.9	8	1700	35	
Ea10a	Mangapepeke trib	38°52'59.35"	174°36'19.97"	67	9	1850	56	SEV, H,
Ea10b	Mangapepeke	38°52'59.35"	174°36'19.97"	149	SD5			
E3	Mangapepeke	38°53'6.46"	174°36'13.06"	133				SEV, H
Ea11	Mangapepeke trib	38°53'9.91"	174°36'14.15"	2	10	2220	37	
Ea12	Mangapepeke trib	38°53'12.55"	174°36'12.55"	1.6	11	2300	25	
Ea13	Mangapepeke trib	38°53'15.16"	174°36'10.57"	9.8	12	2400	74	SEV, H
E4	Mangapepeke	38°53'18.13"	174°36'6.69"	116				SEV, H, F
Ea14	Mangapepeke trib	38°53'24.98"	174°36'8.44"	1.7	13	2700	15	
E5	Mangapepeke	38°53'31.49"	174°36'10.18"	64	SD6			SEV, H, F
Ea15	Mangapepeke trib	38°53'31.39"	174°36'11.01"	5	14	2900	117	
Ea16	Mangapepeke trib	38°53'35.92"	174°36'12.97"	36	15	2960	210	
Ea17	Mangapepeke trib	38°53'37.05"	174°36'10.83"	17	SD7			
Ea18	Mimi trib	38°53'52.14"	174°35'50.83"	6	SD8			
Ea19	Mimi trib	38°53'52.62"	174°35'49.29"	10	16	3800	115	
E6	Mimi trib	38°53'57.34"	174°35'49.00"	21				SEV, H, F
Ea20	Mimi trib	38°54'5.01"	174°35'39.72"	15	Bridge			
Ea21	Mimi trib	38°54'8.19"	174°35'33.84"	3	17	440	22	H
Ea22	Mimi trib	38°54'10.25"	174°35'26.11"	1.5	swale			H
Ea23	Mimi trib	38°54'11.60"	174°35'18.12"	25	18/19	2750	29/43	
E7	Mimi	38°54'13.30"	174°35'15.12"	919				SEV, H, F
Ea24	Mimi trib	38°54'17.86"	174°35'5.89"	13	20	5150	40	
Ea29	Mimi trib	38 54'24.33"	174 34'46.06	12	21	5650	34	
Ea25	Mimi trib	38°54'10.92"	174°35'40.50"	208				F
Ea26	Mimi trib	38°54'11.91"	174°35'29.08"	221	restoration			SEV, H
Ea27	Mimi	38°54'19.44"	174°35'30.71"	630	restoration			SEV, H
Ea28	Mimi trib	38°54'18.61"	174°35'26.55"	25	restoration			SEV, H

Note: Survey method: SEV = SEV + macroinvertebrate samples, H = habitat assessment, F = fish survey.

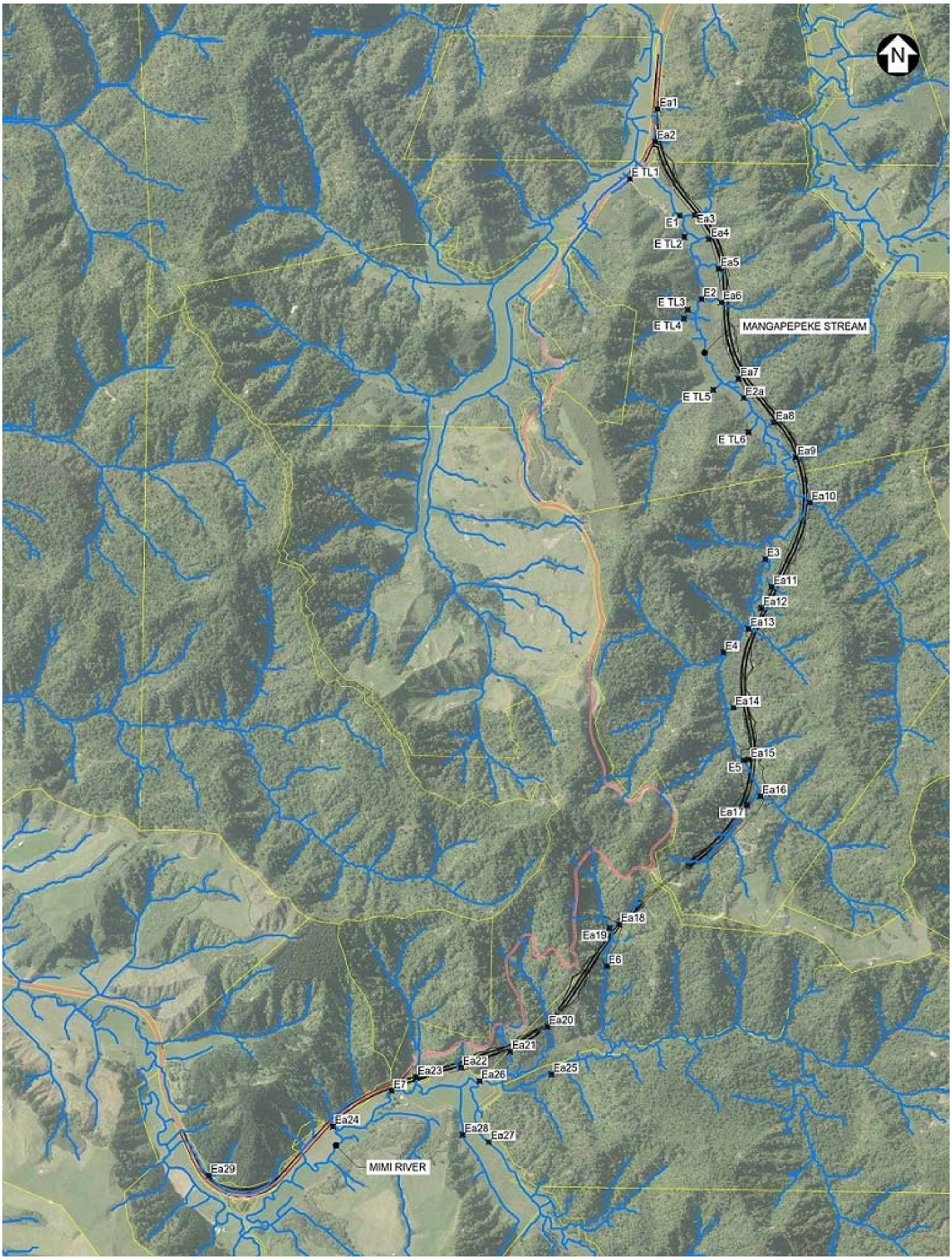


Figure 2.1a - Overview of waterways potentially affected by the Project.

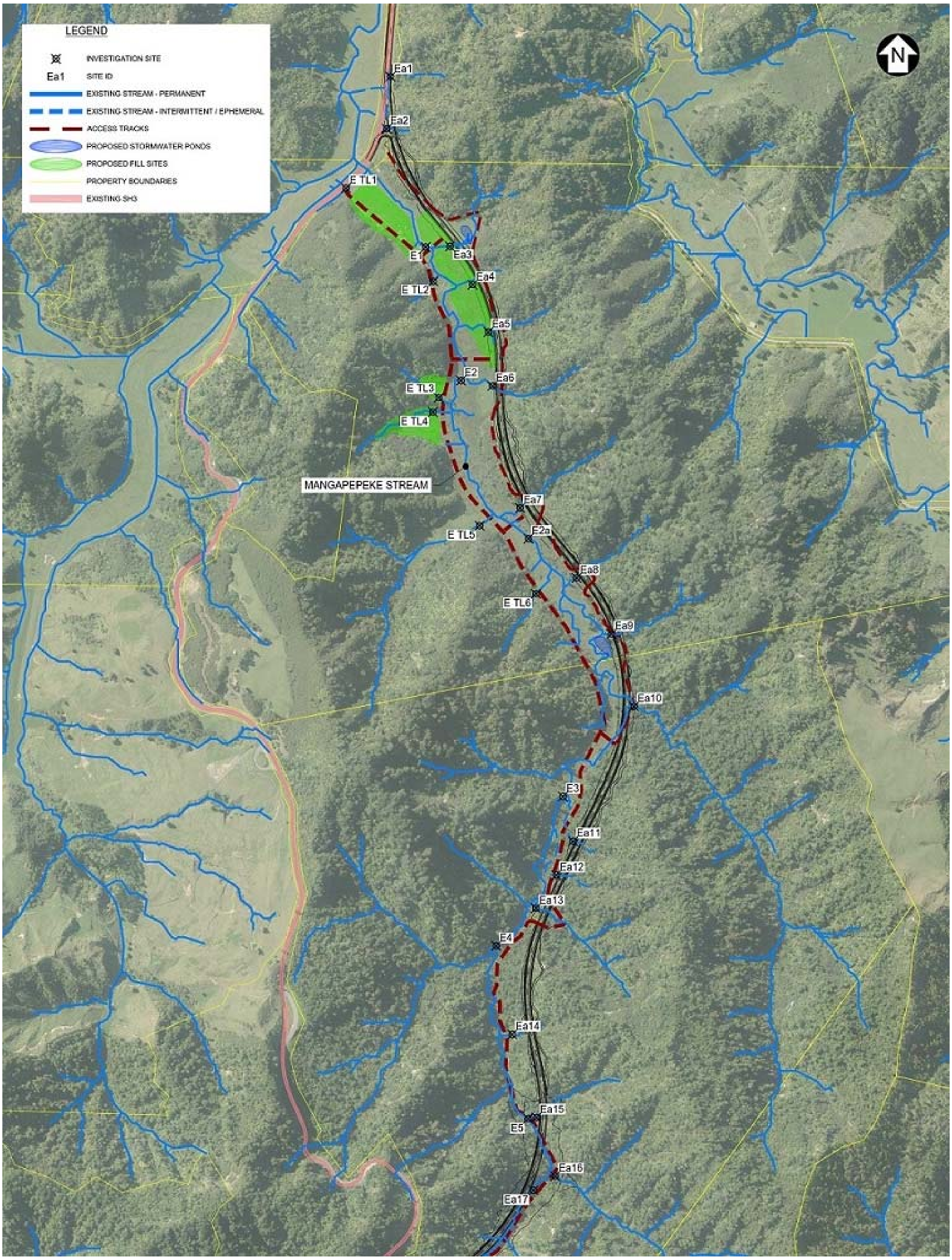


Figure 2.1b - Location of waterways potentially affected by the Project and stream surveys in Mangapepeke Stream catchment.

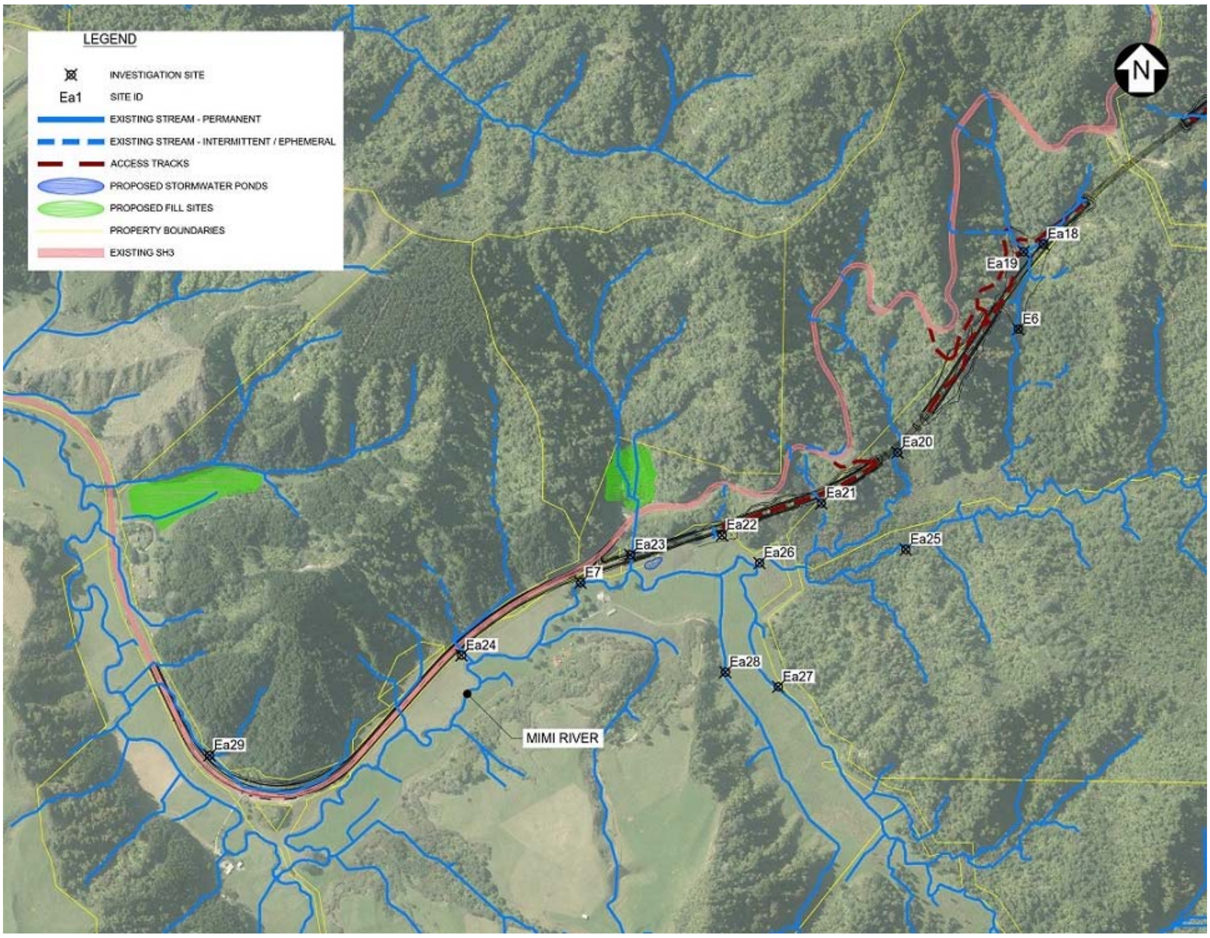
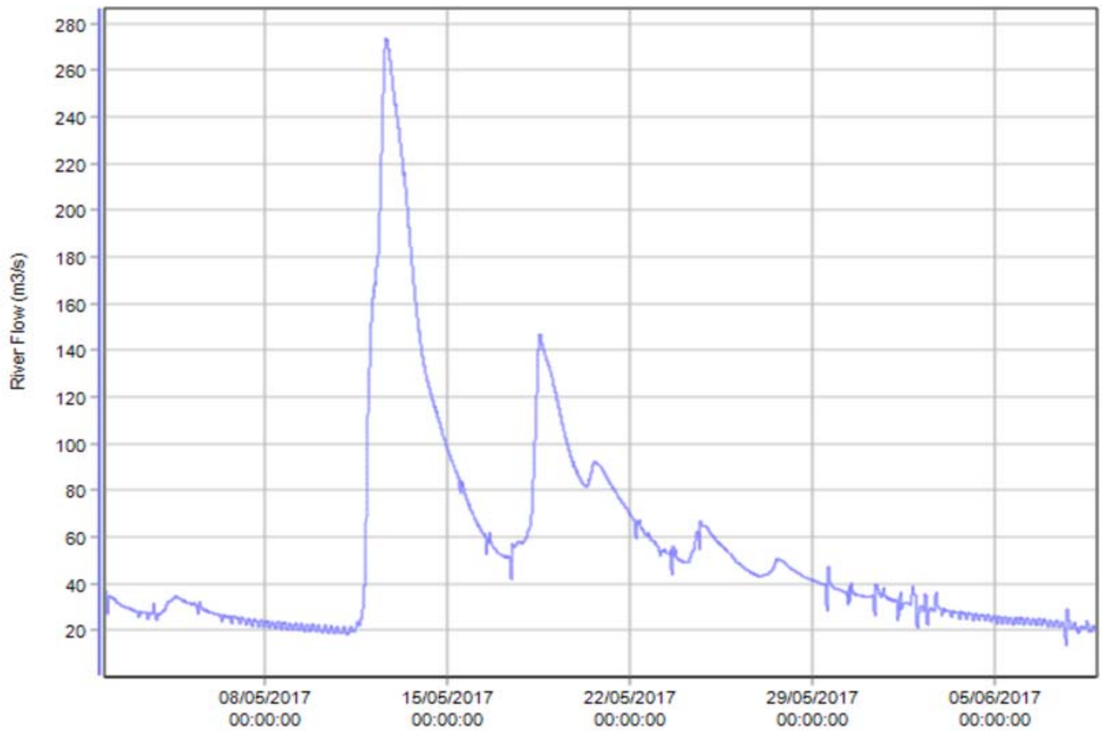


Figure 2.1c - Location of waterways potentially affected by the Project and stream surveys in Mimi River catchment.

2.3 Timing of survey work

Site visits of streams within or near the Project area were undertaken during 6-9 June 2017 and 31 July - 1 August 2017. In the week preceding the June survey there had been about 10mm of rainfall, and in the week preceding the August survey there had been about 25mm of rainfall (Uruti station, Taranaki Regional Council). Very heavy rain (about 50mm) had fallen about 10 days prior to the survey. Flow data were not available for the Mangapepeke Stream and the Mimi River so the flow in the Mokau River (19 km to the north) was used as a proxy site. The Mokau River had high flows about two weeks prior to the June survey and about a week prior to the August survey (see Figure 2.2). The potential for these recent flood events to affect aquatic macroinvertebrate communities is discussed with the results; the overall impact on results is expected to be small.



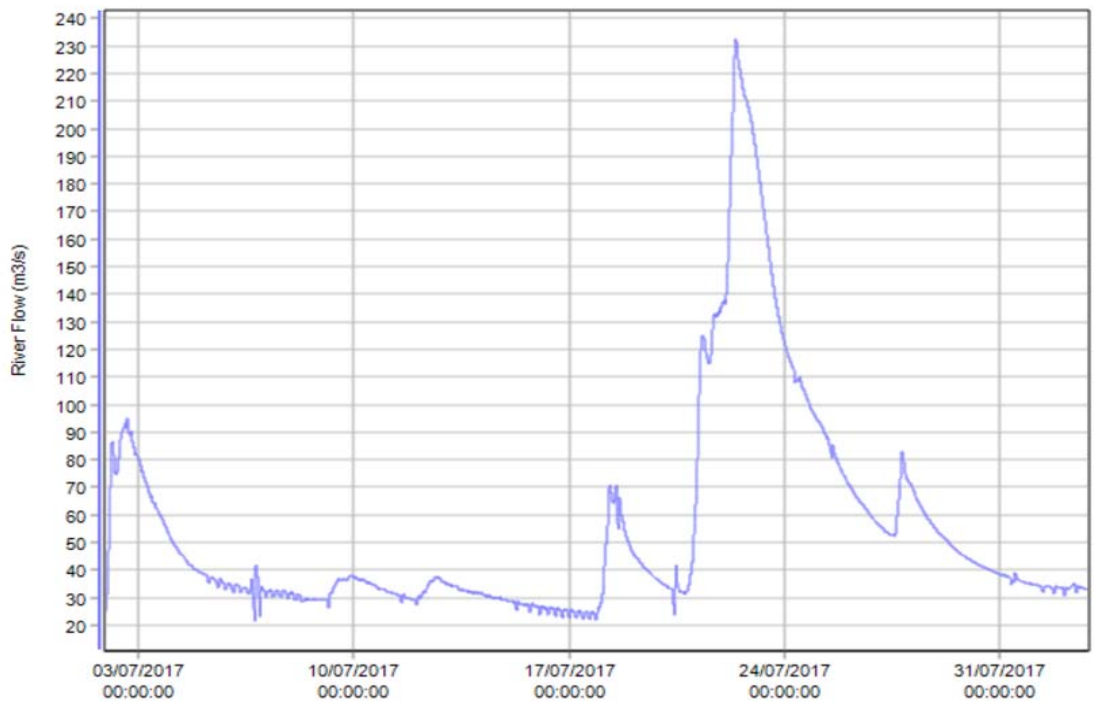


Figure 2.2 – Flow in the Mokau River prior to the surveys in June and August (source Waikato Regional Council)

2.4 Habitat measurement

At all sites measurements were made of stream width, water depth (mid-channel), water velocity, macrophyte cover and riparian vegetation type. The habitat was assessed and scored using the national rapid habitat assessment protocol (Clapcott 2015) (Appendix 1). Other habitat variables were assessed as part of the SEV method.

2.5 Fish surveys

Fish abundance and diversity were surveyed at six sites along the route. The electro-fishing method was used at three sites (E4, E5, and E6); these sites were suitable for electro-fishing because they were relatively shallow and the substrate relatively firm. Fyke nets and/or traps were used at three sites in the lower section of the Mangapepeke Stream (Site E1) and the Mimi River (Sites E7 and Ea25), where the streams were sufficiently large and deep (Figure 2.1).

The electro-fishing used a Kainga BMP300 electrofishing machine with a pulse rate of 50 pps and pulse width of 2.5ms. At each site about 150m of stream length was electro-fished following the protocols described in Joy et al. (2013). The survey reach was fished from downstream to upstream in 5 to 10 sub-sections; within which about 3m lengths were fished from upstream to downstream towards a pole-netter. Captured fish were stored in a container for identification and measurement after each sub-reach was fished. Any kōura or shrimp caught in the fish survey were also recorded. Fish and kōura (*Paranephrops planifrons*) were released back into the stream after counting and measurement.

The netting of site E1 and E7 (undertaken in June) used six fine mesh fyke nets were set over night at each site. The traps were baited with cheese. The fyke net design followed the recommendations in Joy et al. (2013). They were fine mesh (mesh size ca. 4mm) with net dimensions of: six hoops, with 60cm wide front D-mouth, and 3m long trap and 5m long leader. Each net had an exclusion barrier to prevent large fish entering the final chamber.

Site Ea25 is a tributary of the Mimi Stream within the Kahikatea swamp forest (sampled in early August). The stream was too deep (about 1m) to electric fish and the pools were too small or narrow to use the standard fine-mesh fyke nets. At this site, smaller fyke nets were used in addition to fine mesh Gee-minnow traps. The fyke nets had a mesh size of about 12mm with dimensions of: 5 hoops, with a 40cm wide front mouth, a 2.4m long trap and a 2.5m long leader.

Likely fish species present in the streams were also assessed by using the results of previous survey (eg Hamill 2017) and searching in the NZ Freshwater Fish database.

2.5.1 Fish Index of Biological Integrity (Fish IBI)

The results of the fish survey were used to calculate an Index of Biological Integrity (IBI) using the approach and tools in Joy (2007). The Fish IBI compares the presence and absence of fish found in a particularly stream with what is expected in the stream based on the site's elevation and distance from the coast. The Fish IBI was used in calculating the Stream Ecological Valuation (SEV).

2.6 Aquatic macroinvertebrates

The use of macroinvertebrates for assessing the condition of streams is widespread in New Zealand and overseas. The structure and composition of macroinvertebrate communities is a good indicator of stream condition as they are found in almost all freshwater environments, are relatively easy to sample and identify, and different taxa show varying degrees of sensitivity to pollution.

A single macroinvertebrates sample was collected at all sites where the SEV was being calculated. These were sites E2, E3, E4, E5, E10, E13 in the Mangapepeke Stream catchment and sites E6, E7, E25, E26, E27 and E28 in the Mimi River catchment (Figure 2.1).

Aquatic macroinvertebrate samples were collected using a kick net (D-shape, 0.5mm mesh size). At most sites sampling followed the semi-quantitative method for soft bottomed streams - Protocol C2 of Stark et al. (2001). Stable habitat features (eg bank margin, woody debris, macrophyte and gravel substrate) were sampled according to their occurrence in the reach. At sites E5 and E6 the substrate allowed the semi-quantitative method for hard-bottomed streams to be used (Protocol C1 of Stark et al. 2001) with woody debris also sampled when it was encountered.

Macroinvertebrate samples were preserved in alcohol and processed using Protocol P2 (200 fixed count and scan for rare taxa) of the Protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001).

The following ecological indices were calculated to assess the biological health of the river:

- Taxa Richness. This is a measure of the types of invertebrate taxa present in each sample.
- EPT richness and EPT abundance (Ephemeroptera-Plecoptera-Trichoptera). This measures the number of pollution sensitive mayfly, stonefly and caddisfly (EPT) taxa in a sample (excluding *Oxyethira* and *Paroxyethira*) and is an indicator of long-term water quality.
- Macroinvertebrate Community Index (MCI). The MCI is an index for assessing the water quality and 'health' of a stream using the presence/absence of macroinvertebrates (Stark 1985).
- Quantitative MCI (QMCI). The QMCI is similar to the MCI but is based on the relative abundance of taxa within a community (Stark 1993, Stark 1998).

The MCI and QMCI reflect the sensitivity of the macroinvertebrate community to pollution and habitat change, with higher scores indicating higher water quality. Generally accepted water quality classes for different MCI and QMCI scores and the soft-bottomed variations (MCI-sb and QMCI-sb) are shown in Table 2.2.

Table 2.2– Suggested quality thresholds for interpretation of the MCI and QMCI from Stark (1998)

Quality Class	Description	MCI	QMCI
Excellent	Clean water	> 120	> 6.0
Good	Doubtful quality or possible mild pollution	100 – 120	5.0 - 6.0
Fair	Probable moderate pollution	80 – 100	4.0 – 5.0
Poor	Probable severe pollution	< 80	< 4.0

2.7 Stream Ecological Valuation (SEV)

The Stream Ecological Valuation (SEV) method was used to assess the ecological value of streams at 11 sites along the proposed Route using the method described in Storey et al. (2011), Neale et al. (2011) and Neale et al. (2016).

Streams and waterways provide a number of ecological functions. The SEV is a standard method for assessing stream values and quantifying loss and any requirements for offset compensation. It classifies stream functions as:

- Hydraulic functions (ie processes associated with water storage, conveyance, flood flow retention and sediment transport);
- Biogeochemical functions (ie processes associated with processing of minerals, particulates and water chemistry);
- Habitat provision functions (ie the type, amount and quality of habitat for flora and fauna); and
- Native biodiversity functions (ie the occurrence of diverse populations of indigenous native plants and animals) (Rowe et al. 2008).

The results of the survey were entered into the SEV calculator version 2.3 to calculate SEV scores. Reference site values were based on SEV scores from pristine steams. The reference sites used were site E6 (Mimi River tributary), and site N7 (Mangapepeke Stream) and W1 (Waipingao Stream); the latter two sites had previously been surveyed in February 2017 by Hamill (2017).

SEV surveys were undertaken along the main stem of Mangapepeke Stream and Mimi River and representative tributaries. For other tributary streams affected by the route, an SEV score was assigned based on scores from representative streams with similar habitat.

A fish survey was not undertaken at all sites where an SEV survey was applied. In these situations, the likely fish present at the site was based on what had been found in nearby fish surveys of similar habitat. For some sites additional fish and/or, invertebrates were assumed to be present even if they had not been caught. This was based on the suitability or habitat and nearby fish records; it recognises the limitations of a single fish survey at a particular site. Specific changes were:

- Freshwater mussels (kākahi) were observed at sites E1 (Mangapepeke Stream) and E7 (Mimi Stream) so kākahi were also assumed to be present at sites upstream of those sites with suitable habitat (ie Sites E2, E7, Ea10, Ea26 and Ea27).
- It was assumed that kōura were present at all forested sites surveyed regardless of whether they were caught, because past surveys found them to be widespread.
- At site E5 it was assumed that banded kōkopu and longfin eel would also be present in addition to the redfin bully caught during the fish survey based on habitat.
- At site E6 it was assumed that redfin bully would also be present in addition to the banded kōkopu based on the habitat present.
- Giant kōkopu were only caught in the Mimi River but were also assumed to be in the Mangapepeke Stream at site Ea10 based on the habitat present.

2.7.1 Environmental Compensation Ratio (ECR)

The SEV scores were used to calculate an Environmental Compensation Ratio (ECR). The ECR determines the amount of another stream reach that would need to be restored relative to the amount of stream degraded, in order to achieve no net loss of stream ecological function. It is intended to apply to similar types of streams. Calculation of an ECR accounts for both functions actually degraded as a consequence of the development, and also the potential for improvement in these functions that is forgone by development of the site.

The ECR formula gives the number needed to multiply the area of the impacted stream by, to determine what stream area needs to be restored as part of an offset /compensation package, in order to replace the functions lost in the impacted stream. An ECR score less than 1 defaults to 1 (Storey et al. 2011).

ECR = [(SEVi-P – SEVi-I)/(SEVm-P – SEVm-C)] x 1.5

Where:

SEVi-C & SEVi-P are the current and potential SEV values respectively for the site to be impacted.

SEVm-C & SEVm-P are the current and potential SEV values respectively for the site where environmental compensation is to be applied.

SEVi-I is the predicted SEV value of the stream to be impacted, after impact.

The length of stream requiring restoration was calculated by first multiplying the length of stream being piped or diverted during the Project by the ECR (Appendix C). This was then multiplied by the average stream width, and expressed as stream area to ensure ‘no net loss’ of overall habitat. There will be little difference in an analysis based on area or length if the impact and offset compensation streams are of similar size, but it can make a difference if they are of different sizes. The use of stream area helps put more weight on streams with a larger quantum of aquatic habitat.

2.7.1.1 SEV after impact (SEVi-I)

In calculating the ECR, a lower after impact SEV was used for culverted streams (ie SEVi-I of 0.23) compared to streams that will be diverted or temporarily impacted (e.g. from access tracks). The 'after impact' score was calculated by applying a hypothetical scenario within the SEV calculator using expert judgement; it is consistent with experience from other projects.

The ECR equation was not designed for stream diversions where the final stream values will be similar or better than the current stream values. Some assumptions embedded in the ECR equation don't apply to stream diversions, eg unlike a piped stream, a stream diversion usually does not lose the potential for future restoration work to occur. Furthermore, if the ECR equation is applied to stream diversions the resulting ECR is often zero or cannot be defined because the denominator is zero.

For stream diversions where the final stream condition will be similar to before the works, a standard ECR value of 0.5 times was used, instead of applying the ECR equation. This means restoration of the stream diversion section plus offset compensation of another 50% of the stream diversion length /area. This is consistent with the SEV approach to account for temporary degradation during the period of the works and time lags in establishing restoration plantings. This applies to the stream diversion at site E7 and stream diversions at fill sites (ETL3, ETL4, ETL5, Ea30).[2]

It is unlikely that streams that are surrounded by high quality forest habitat will be returned to equivalent conditions after stream diversions – especially in the case of steep confined catchments. In these situations, the ECR equation was applied based on a hypothetical estimate of the stream diversion condition after the works and establishment of riparian vegetation. This applies to the stream diversions at site E5, Ea17 and Ea18.

The same approach was taken for short-term works where the impact will be limited to the construction period with restoration occurring after this period. Where the restoration will eventually result in a stream having similar habitat condition than before the works, then a ECR value of 0.5 times was applied, ie restoration of the affected length plus offset compensation of another 50% of the length/area. This addresses the time lag required for riparian vegetation to establish to a similar condition as before the works (e.g. sites ETL3, ETL4, Ea3, Ea4, Ea5, Ea7, Ea8, Ea9, and E3).

For short term works and stream diversions, where the after impact SEV score may be lower than the current score, the ECR was based on current state[3] and any ECR values that were less than 0.5 defaulted back to 0.5.

2.7.1.2 SEV after restoration (SEVm-P) and SEV potential (SEVi-P)

The 'potential' SEV score for sites was based on applying hypothetical scenarios within the SEV calculator using expert judgement. For streams of similar habitat and SEV values then the SEV value assumed after restoration efforts (SEVm-P) was the same as the potential SEV (SEVi-P) used in the calculation.

[2] The approach is conservative for stream being diverted with low current SEV scores, because the new channel can be rapidly restored to current state. However only site Ea30 is likely to meet this criteria.
[3] This is because the stream potential is not lost; in practice, it made very little difference to the ECR.

It was assumed for the purpose of calculating ECRs, that restoration for the purpose of stream offset compensation would occur along the upper valley of the Mangapepeke Stream (eg near Sites E3 and E4) and in the Mimi River catchment (eg near Sites Ea26, Ea27, Ea28 and E7). The availability of restoration sites is still to be confirmed. The potential improvements in SEV from restoration work will need to be validated once the compensation package has been confirmed.

The ECR equations used an average value for habitat improvements expected at stream offset sites. The length of the Mangapepeke Stream and Mimi River that might be improved with restoration work was estimated. The difference between current and potential (after restoration) SEV was estimated (ie SEVm-P minus SEVm-C), and weighted by the stream area of each section (stream length times width). From this an area-weighted average SEV improvement was calculated for use in the ECR equations (Appendix C).

2.7.1.3 Adjusting the ECR

It should be remembered that the SEV is simply a tool and expert judgement is needed in any final decision about appropriate mitigation and offset compensation. In particular, the SEV approach only partially accounts for the rare and complex stream habitat associated with mature swamp forest. A remnant of degraded kahikatea swamp forest is present in the Mangapepeke Stream upstream of site Ea10. The stream morphology through this section has mostly maintained its complex character despite the degraded condition of the forest itself. The Mangapepeke Steam in this area is relatively narrow and deep with stream banks stabilised by the tree roots. This morphology is hard to recreate in a stream restoration until the floodplain forest has matured. To recognise this longer than usual time-lag for restoration, the ECR values for site Ea10 were doubled (Appendix C).

2.7.1.4 Measuring lengths of streams affected by the works

The length of streams affected by the works was measured from aerial photographs with an overlay of the route footprint. The lengths affected were measured separately for the permanent footprint and disturbance from temporary works outside the footprint. It was assumed that culvert headwalls and aprons would extend beyond the permanent footprint, so an additional impacted length of 5m and 10m was added for streams with catchment areas of <20ha and >20ha respectively.

Access tracks were assumed to be 8m wide. Where access tracks follow an existing farm track an additional 5m of culvert was allowed. Where access tracks were new, an additional 10m of culvert was allowed.

2.8 Assessment of effects scoring method

The assessment of ecological effects follows Ecological Impact Assessment guidelines (EcIA) produced by the Environment Institute of Australia and New Zealand (EIANZ, 2015). The aim of using a standard framework and matrix approach is to provide a more consistent and transparent assessment of effects. It provides structure but does not replace the need for sound ecological judgement.

2.8.1 Step 1: Assess ecological values

Ecological values were assigned on a scale of 'Low' to 'Very High' based on species, communities, and habitats. These were scored using criteria in the EcIA guidelines (see Table 2.3).

Unlike for terrestrial ecosystems there is no unifying set of attributes used to assign value to freshwater systems. Matters that may be considered when assigning ecological value to freshwater systems include: representatives, rarity/distinctiveness, diversity and the ecological context.

The SEV score can be used to contribute to an assessment of ecological value (although its primary purpose is quantifying offset /compensation for stream loss). Also, the concept of Ecological Integrity can be used. Ecological Integrity is the degree to which ecosystems reflect reference conditions with negligible human impact. Schallenberg et al. (2011) discussed Ecological Integrity in terms of:

- Nativeness: the degree to which an ecosystem's structural composition is dominated by the indigenous biota characteristic of the particular region.
- Pristineness: relates to a wide array of structural, functional and physico-chemical elements (including connectivity), but is not necessarily dependent on indigenous biota constituting structural and functional elements.
- Diversity: richness (the number of taxa) and evenness (the distribution of individuals amongst taxa); link to a possible reference condition.
- Resilience (or adaptability): quantifying to the probability of maintaining an ecosystem's structural and functional characteristics under varying degrees of human pressure.

Table 2.3 – Assignment of values within the Project footprint to species, vegetation and habitats (adapted from EIANZ, 2015)

Value	Species Value requirements
Very High	Important for Nationally Threatened species
High	Important for Nationally At-Risk species and may provide less suitable habitat for Nationally Threatened species
Moderate	No Nationally Threatened species, no or very poor habitat for At-Risk species, but habitat for locally uncommon or rare species
Low	No nationally Threatened, At-Risk or locally uncommon or rare species

2.8.2 Step 2: Assess magnitude of effect

Magnitude of effect is a measure of the extent or scale of the effect and the degree of change that it will cause. Effects were assessed in terms of intensity, spatial scale, duration, reversibility, and timing. Risk/uncertainty and confidence in predictions was also considered. Effects magnitude was scored on a scale of ‘No Effect’ to ‘Very High’ (Table 2.4). The assessment was made both without mitigation and with mitigation (but not offset).

The spatial scale for effects such as habitat loss was considered in the context of the streams catchment or sub-catchment upstream of the Project area. Judgement is required in assessing the magnitude of effect in the context of the spatial scale.

Table 2.4 – Summary of the criteria for describing the magnitude of effect (EIANZ, 2015).

Magnitude of effect	Description
Very High	Total loss or alteration of the existing baseline conditions; Loss of high proportion of the known population or range
High	Major loss or alteration of existing baseline conditions; Loss of high proportion of the known population or range
Moderate	Moderate loss or alteration to existing baseline conditions; Loss of a moderate proportion of the known population or range
Low	Minor shift away from existing baseline conditions; Minor effect on the known population or range
Negligible	Very slight change from the existing baseline conditions; Negligible effect on the known population or range

2.8.3 Step 3: Level of effects assessment

An overall level of effect was using a matrix approach that combine the ‘ecological values’ and the ‘magnitude of effects’ on these values. The matrix describes a level of ecological effect on a scale of ‘No Effect’ to ‘Very High’ (Table 2.5).

The level of effect can be used as a guide to the extent of response in terms of avoidance, mitigation and, if necessary, biodiversity offsetting.[4]

[4] Biodiveristy offsets are measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground.

Table 2.5 – Criteria for describing overall levels of ecological effects (modified from EIANZ, 2015) .

Magnitude of effect	Ecological Value			
	Very High	High	Moderate	Low
Very High	Very High	Very High	High	Moderate
High	Very High	High	Moderate	Low
Moderate	High	High	Moderate	Low
Low	Moderate	Low	Low	Very Low
Negligible	Low	Very Low	Very Low	Very Low
No effect	No effect	No effect	No effect	No effect

3 Existing environment / survey results

3.1 Overview of existing environment

The Mt Messenger area is situated in the North Taranaki Ecological District. The area contains high quality habitat for indigenous terrestrial and aquatic flora and fauna. The geology is dominated by papa mudstone; this has a considerable influence on stream substrate, the gravels are soft and there is a relatively high amount of fine sediment on the stream bed. The proposed route spans two hydrological catchments: the Tongaporutu River to the north (for which the Mangapepeke Stream is a tributary) and the Mimi River to the south.

3.1.1 Mangapepeke Stream

The Mangapepeke Stream drains north-west to the Mangaongaonga Stream and the Tongaporutu River, which enters the coast at Tongaporutu, about 7km north of the Project footprint. The lower section of the Mangapepeke Stream (near the current SH3) is a small low gradient stream about 1.4m wide and 0.4m deep in runs with occasional deep pools.

The catchment is predominantly covered in indigenous forest but the valley through which the stream meanders is mainly pasture and grazed wetland. More wetland vegetation remains where the ground is poorly drained. In places near the current SH3 the stream has been straightened, but the stream meanders through most of the Mangapepeke valley. The substrate is silt with occasional wood becoming more common further up the catchment. Aquatic macrophytes common in the stream included watercress (*Nasturtium officinale*), starwort (*Callitriche stagnalis*) and native charophyte (stonewort) *Chara* sp. The streams in the valley have high potential to be enhanced by removing stock and riparian planting.

A remnant of degraded kahikatea swamp forest is present on the true right of the Mangapepeke valley near site Ea10. The forest condition has been degraded by stock grazing, nevertheless the stream through this small section has maintained much of its complex original complex morphology, ie relatively narrow and deep with tree roots stabilising the stream banks and forming pools, undercuts and small cascades. The streams in the valley have high potential to be enhanced by excluding stock, and riparian planting.

The upper reaches of the Mangapepeke Stream and most tributaries entering from the valley sides typically have a steep gradient, cascade-pool morphology and indigenous forest cover. The sections with dense forest cover are wider and shallower (about 2.5m wide and 0.25m deep at site E5) and have deep pools downstream of cascades and log jams. Waterfalls are common (eg sites Ea14, Ea15, and E5). Further up the main valley becomes very narrow (about 1.5 to 2.5m wide at the base) and is confined with steep sides (ie sites Ea16 and Ea17).

Fish caught in the lower reaches include: longfin eel (*Anguilla dieffenbachii*), adult inanga (*Galaxias maculatus*), redfin bully (*Gobiomorphus huttoni*), and common bully (*Gobiomorphus cotidianus*). Paratya shrimp (*Paratya* sp.), freshwater crayfish (koura) and freshwater mussel (kākahi; *Hyridella* sp.) were also common. Steeper sites tended to have banded kōkopu (*Galaxias fasciatus*), redfin bully and kōura.

The aquatic macroinvertebrate community indicated 'fair' to 'good' water quality in the lower reaches, improving to 'good' and 'excellent' water quality further upstream. However, some tributaries have been recently dug out and straightened (eg site Ea3) and this has considerably reduced the habitat values.

3.1.2 Mimi River

The Mimi River flows south-west to enter the coast between Waiiti and Urenui. The lower section near the current SH3 is a low gradient stream about 2.1m wide and 0.45m deep in runs with occasional deep pools. The catchment is predominantly covered in indigenous forest but the valley through which the main stream meanders is mainly pasture and grazed wetland (sites E7, Ea27 and Ea28). The aquatic macrophytes *Potamogeton sp.* and the aquatic weed *Elodea canadensis* are present in the lower reaches. The streams in the valley have high potential to be enhanced by excluding stock and riparian planting.

There is a kahikatea swamp-maire (*Syzigium maire*) swamp-forest downstream of tributaries affected by the proposed route. The stream through this section is narrow (about 1.1m) and deep (1m) with a complex morphology. This kahikatea forest has high ecological value because it is hydrologically intact and only a very small percentage of the original area of this forest type remains in the region. It offers high quality habitat suitable for wetland birds including fernbird (*Megalurus punctatus*) and spotless crake (*Porzana tabuensis*) (also see the Ecological Effects Assessment - Vegetation (Technical Report 7a, Volume 3 of the AEE).

Fish caught in the lower reaches of the Mimi River include: longfin eel, adult inanga, redfin bully, giant kōkopu (Galaxias argenteus) and banded kōkopu. Paratya shrimp, kōura and kākahi were also common. Steeper sites tended to have banded kōkopu, and kōura. Many of the fish species present are classified as all At Risk - Declining (ie longfin eel, inanga, giant kōkopu and redfin bully).

The aquatic macroinvertebrate community indicated 'excellent' water quality/ condition along the main stem of the river and forested headwater streams. However small tributaries running through pasture were heavily modified and affected by stock (eg cattle pugging). These had macroinvertebrate community's indicative of 'poor' ecological condition (ie site Ea28).

3.2 Habitat

The highest habitat scores (sites E5, E6, Ea10, Ea13, Ea21) occurred at sites with indigenous forest dominating the catchment. This provided shade and woody debris in the streams which in turn provided a diversity of cover and habitat for fish and invertebrates. Site Ea10 in the Mangapepeke Valley was located within a degraded remnant of a kahikatea swamp forest, and although the stream had limited shading it had high potential fish habitat and hydraulic complexity. The sites with the lowest (worst) habitat scores (Ea1, Ea22 and Ea28) were characterised by having little riparian vegetation cover, no shade, little cover for fish, uniform hydraulic conditions, considerable sedimentation and bank erosion accelerated by cattle access.

The geology of Mt Messenger is papa mudstone. This is a relatively soft rock and the gravel and cobbles are readily crushed to silt by hand. Small slips were common in the vicinity of the proposed route. In low gradient sections, the stream substrate in both the Mangapepeke Stream and Mimi Stream predominantly consisted of fine sediment (eg sites E1, E2, E3, E7, Ea26, Ea27). In steeper sections of the stream (E4, E5, E6, Ea13) gravels or cobbles formed more of the substrate. Even in the steep sections fine sediment was common in runs and pools (Table 3.1, Table 3.2).

Bank slumping and cattle near the streams had an observable impact on fine sediment within runs on the stream bed. In some cases, pugging by cattle caused complete smothering of the bed of smaller streams/drains (eg site Ea28).

All of the sites had a Regional Environment Classification (REC) climate category of wet and warm; source of flow is low elevation; and geology classed as soft sedimentary. Land cover was classed as pastoral for sites for the lowland sites, and indigenous forest for the upper Mangapepeke Stream.

Fly tipping from the top of Mt Messenger has resulted in rubbish and exotic weeds being transported down into both the Mangapepeke and Mimi catchments. As a result, pest plants such as wandering jew (*Tradescantia* sp.) and Arum lily (*Zantedeschia aethiopica*) occur in otherwise near pristine areas.

Most waterways directly impacted by the Project works are small; a third (10) have a catchment area of less than 5ha (probably intermittent or ephemeral), and about three quarters (22) have a catchment area of less than 20ha (Table 3.3).

Table 3.1 – Habitat scores for streams on Mt Messenger affected by the Project (Clapcott 2015). High scores indicate better habitat quality.

	Mangapepeke catchment								Mimi catchment						
Habitat parameter	**E1**	**E2**	**E2a**	**E3**	**E4**	**E5**	**Ea10**	**Ea13**	**E6**	**E7**	**Ea21**	**Ea22**	**Ea26**	**Ea27**	**Ea28**
Deposited sediment	1	1	1	1	5	5	4	5	6	1	3	1	3	1	1
Invertebrate habitat diversity	4	3	7	4	7	7	8	8	9	8	8	1	7	5	1
Invertebrate habitat abundance	4	4	2	5	5	8	6	7	7	3	6	5	5	3	2
Fish cover diversity	4.5	5.5	6	4	7	7	9	8	9	7.5	8	3	7	5	2
Fish cover abundance	6	4	7	7	4	8	9	5	6	6	4	7	9	8	3
Hydraulic heterogeneity	4	8	7	7	7	8	10	6	8	7	6	1	7	8	4
Bank erosion	3	6	4	7	5	7	3	7	8	6	7	5	3	4	4
Bank vegetation	2	8	7	4	3	8	5	8	10	2	8	3	5	2	2
Riparian width	1	1	1	1	8	10	6	10	10	1	10	1	4.5	1	1.5
Riparian shade	4	4	5.5	1	4	8	6	9	9.5	3	9	1	3	1.5	1
Total score (out of 100)	**33.5**	**44.5**	**47.5**	**41**	**55**	**76**	**66**	**73**	**82.5**	**44.5**	**69**	**28**	**53.5**	**38.5**	**21.5**

Each habitat parameter scored on a scale of 1 to 10

Table 3.2 – Percentage of substrate on the stream bed of different size and type. Measured using the SEV method, ie 100 points assessed in stream reach with organic material recorded separately as overlying inorganic or wood material. Highlighted cells show the dominant inorganic substrate (ie the substrate covering >50% of the stream bed)

Site	Inorganic material									Wood			Organic material		
	Si/Sa	SG	SMG	MLG	LG	SC	LC	B	BR	small	medum	large	Leaf litter	Periphyton, roots, macrophytes	Roots
E2	97										1	2		44	10
E3	95									2	3		1	47	4
E4	17	8	14	19	23	6	3			3	3	4	2		3
E5	16	2	9	11	9	11	23	7	4	2	3	3	3		
E6	12	9	15	11	21	18	5	1	2	3	3		12	2	2
E7	66	2	1	2	5	2	4	1	8	6	1	2		24	7
Ea10	57	1	10	12	9		1			5		5	11		17
Ea13	35	6	13	20	17	7	2						4		6
Ea26	97									2	1		3	3	39
Ea27	48		12	16			1		3	2	9	9	4	22	6
Ea28	98									2				38	1

Si = silt, Sa=sand, SMG=small medium gravel, MLG = medium large gravel, LG=large gravel, SC=small cobble, LC=large cobble, B=boulder, BR=bedrock

Table 3.3 – Characteristics of waterways potentially affected by the Project. Some sites could not be visited due to lack of landowner approval (marked ‘no site visit’).

Site	Catchment	catchment area (ha)	ID culvert / diverson	Riparian cover	Morphology	width (m)	depth run	depth pool (m)	comment
Ea1	Mangapepeke trib	3.82	1	indigenous forest	Ephemeral, steep	0.3	0.03	0.05	No fish passage through existing culvert. Replace existing culvert
Ea2	Mangapepeke trib	1.80	2	road side, scrub	Ephemeral cut-off drain	0.2			Ephemeral road cutoff drain no waterway.
E1	Mangapepeke	328		pasture	meander	1.4	0.4	0.8	
Ea3	Mangapepeke trib	6.3	3	pasture, grazed wetland	tbc	*0.5*			Drain dug out in Autumn.
Ea4	Mangapepeke trib	1.8	4	pasture, grazed wetland	Ephemeral	*0.2*			no site visit
Ea5	Mangapepeke trib	4.2	5	pasture, grazed wetland	tbc	*0.5*			no site visit
E2	Mangapepeke	306		pasture, grazed wetland	meander	1.4	0.4	0.8	Drains recently excavated. Cattle access to stream
Ea6	Mangapepeke trib	4.4	swale	pasture, forest	tbc	*0.5*			no site visit
Ea7	Mangapepeke trib	6.8	6	pasture, grazed wetland	tbc	*0.5*			no site visit
E2a	Mangapepeke	248		pasture, degraded	meander	1.3	0.4	0.5	Single row of manuka along stream edge near this
Ea8	Mangapepeke trib	5.8	7	pasture, grazed wetland	tbc	*0.5*			no site visit
Ea9	Mangapepeke trib	7.9	8	pasture, grazed wetland	tbc	*0.65*			no site visit
Ea10a	Mangapepeke trib	67	9	Pasture/swamp forest	meander	1	0.3	1.5	Tributary. Pools >1.2m with 0.8m drops in confined sections
Ea10b	Mangapepeke	149	SD5	Pasture/swamp forest	meander	1.2	0.4	1.5	Main stem through Kahikatea reminant. Drops of about 0.8m from root mass forming deep pools. Bank height 0.6 to 1.2m (typically 0.7m)
E3	Mangapepeke	133		pasture, grazed wetland	meander	1.25	0.35	0.45	Cattle causing pugging.
Ea11	Mangapepeke trib	2	10	indigenous forest	Ephemeral,	0.2	0.01		Ephemeral disappears in wet ground.
Ea12	Mangapepeke trib	1.6	11	indigenous forest	Ephemeral,	0.2	0.01		Ephemeral, only a trickle despite the rain.
Ea13	Mangapepeke trib	9.8	12	indigenous forest &	step-pool	0.75	0.1	0.3	Narrower through pasture (0.65m wide and 0.1m
E4	Mangapepeke	116		indigenous forest, grazed wetland	riffle-run	1.8	0.25	0.4	Cattle access causing pugging and erosion. Vegetation in poor condition and open.
Ea14	Mangapepeke trib	1.7	13	indigenous forest	step-pool, waterfall	0.3	0.01	0.2	Very steep, >12m waterfall below the alignment.
E5	Mangapepeke	64	SD6	indigenous forest	riffle-run	2.5	0.25	1.5	Waterfall at upstream extent of reach.
Ea15	Mangapepeke trib	5	14	indigenous forest	step-pool, waterfall	0.6	0.1		enters d/s of waterfall. Enters mainstem via a large waterfall.
Ea16	Mangapepeke trib	36	15	indigenous forest	step-pool, waterfall	1.2	0.35		TR branch confined gorge. width 0.8-2m
Ea17	Mangapepeke trib	17	SD7	indigenous forest	step-pool, waterfall	1	0.15	0.5	TL branch confined gorge. width 0.8-1.3m
Ea18	Mimi trib	6	SD8	indigenous forest	step-pool	0.5	0.08		TL = smaller. W 0.4-0.7m. Small stream cobbles. Camera= 11:20.
Ea19	Mimi trib	10	16	indigenous forest	step-pool	0.9			TR channel 2.1m wide.
E6	Mimi trib	21		indigenous forest	riffle-run	1.2	0.15	0.55	Near us end width =1m and drops of about 1.6m
Ea20	Mimi trib	15	Bridge	Swamp forest	meander	0.9	0.1	0.5	swamp forest,puna, miri, SMG/SG. Wandering jew
Ea21	Mimi trib	3	17	indigenous forest	Intermittent, step-pool	0.5	0.02	0.35	Small step-pool forest stream. Intermittent. Second generation, high shade, limited flow diversity.
Ea22	Mimi trib	1.5	swale	pasture	Intermittent, drain	0.4	0.05		Widens to a degraded wetland with heavy stock pugging
Ea23	Mimi trib	25	18/19		drain	0.9			Culvert over farmland
E7	Mimi	919		pasture	meander	2.1	0.46	0.8	Cattle access to stream.
Ea24	Mimi trib	13	20	pasture	drain	0.6	0.1		replace existing culvert. Exit to farm drain.
Ea29	Mimi trib	12	21	pasture	drain	0.6			replace existing culvert
Ea25	Mimi trib	208		Swamp forest	meander	1	1		Kahekatea forest
Ea26	Mimi trib	221	restoration	pasture, forest	meander	1.1	0.4		Raupo TL, wood in stream
Ea27	Mimi	630	restoration	pasture	meander	1.5	0.55		Main flow of Mimi Stm. Top end about 1.2 to 1.7m wide, moderate velocity.
Ea28	Mimi trib	25	restoration	pasture	drain	0.9	0.17	0.4	Farm drain. Tributary enters at Ea28 from hill. Heavy pugging and sedimentation. Width 0.4m at top and 1.2m at lower end. Pools to 0.3m.

3.3 Fish

Fish surveys of streams around Mt Messenger during early June and August 2017 found longfin eel, inanga, common bully, giant kōkopu, banded kōkopu, redfin bully, kōura and Paratya shrimp. Kākahi were also found in both streams (Figure 3.1). The lower gradient streams tended to be dominated by large longfin eel, adult inanga and redfin bully, while the steeper sites tended to have banded kōkopu, redfin bully and kōura – all have good climbing ability (Table 3.5). Longfin eel, giant kōkopu, redfin bully and inanga all have a threat status of ‘At-Risk declining’ (Goodman et al. 2014). Kākahi are in decline around the country, probably due to a combination of declining water quality and recruitment failure due to declining numbers of native fish that are needed as hosts by the juvenile mussel.

The Fish IBI was calculated for each stream. The lower gradient sites on both the Mangapepeke Stream and the Mimi Stream had 'excellent' Fish IBI scores (sites E1, E7, Ea25), while higher up the catchment the scores were 'good' (

Table 3.4). An excellent score means that most regionally expected species for the stream position are present, and that the presence of fish in the stream is similar to sites with minimal human disturbance.

Sampling fish during winter and soon after flood events (eg early August sampling) is not ideal and can find lower fish abundance. However, the diversity of fish caught during the June and August fish surveys were similar to what was found in other tributaries of the Mangapepeke Stream and Mimi River sampled during February 2017. The main difference was that the February surveys found shortfin eel but not giant kōkopu. Also, the February survey of the west branch of the Mangapepeke Stream caught higher abundance of inanga and longfin eel for a similar netting effort (Hamill 2017).

The species found during the sampling are similar to what is recorded in the NZ Freshwater Fish Database (NZFFD) of fish in streams close to Mt Messenger, although the NZFFD also records some marine wanderer species near the coast and koaro (*Galaxias brevipinnis*) in the Ureti Stream. The NZFFD database records:

- A tributary to the Mangaongaonga Stream has records of banded kōkopu, giant kōkopu, longfin eel, inanga, common bully, redfin bully, giant bully, and kōura.
- The Mimi Stream has records of giant kōkopu and eel.
- The Ruhi Stream has records of banded kōkopu, inanga, longfin eel, redfin bully, Paratya shrimp and kōura.
- The Uruti Stream has records of longfin eel, giant kōkopu, redfin bully, koaro, shortjaw kōkopu (*Galaxias postvectis*) and kōura.
- The lower Tongaporutu River has records of inanga.
- The lower Mokau River has records of inanga, longfin eel, shortfin eel (*Anguilla australis*), common bully, redfin bully, kōura, smelt (*Retropinna retropinna*), yellow belly flounder (*Rhombosolea leporine*) and yellow eye mullet (*Aldrichetta forsteri*).
- The Mohakatino River tributary has records of inanga and common bully.

DoC undertook a fish survey of the Taranaki area in 2013 targeting Galaxiid species using spotlighting method, including sites in the Mimi River and Waipingao catchment (Goodman McQueen 2013). The sites surveyed on the Mimi River were at site Ea26 and upstream of site Ea27. The survey found: redfin bully, longfin eel, banded kōkopu, and giant kōkopu. Redfin bully were most abundant. Beds of kākahi were found in the upper Mimi River (upstream of Ea27). All these species were present in the 2017 survey of Mimi River site. It was noted that the presence of large galaxiids was strongly associated with overhanging riparian vegetation and overhead shade.

Table 3.4 – Fish IBI for sites along the proposed Mt Messenger route. High scores indicate more of the expected fish species are present.

Site	Catchment	Distance from the sea (km)	Elevation (m)	Fish IBI	Fish IBI score
E1	Mangapepeke	10.2	13	50	Excellent
E4	Mangapepeke	12.2	20	36	Good
E5	Mangapepeke	12.7	40	26	Good
E7	Mimi	27.5	41	50	Excellent
Ea25	Mimi	28.2	46	54	Excellent
E6	Mimi	28.7	70	36	Good

Figure 3.1 – Some typical fish and bivalves in Mangapepeke Stream and Mimi River. From top to bottom: adult inanga (site E1), redfin bully (site E1), giant kōkopu (site E7), kākahi (site E1).

Table 3.5 – Fish and invertebrates caught along the proposed route, June and August 2017.

Site E7, Mimi River. 6 fine mesh fyke nets over 160m left overnight. June 2017

Species		**0+**	**Small**	**Med**	**Large**	**Total**
Longfin eel	*Anguilla dieffenbachii*			5	4	**9**
Giant kokopu	*Galaxias argenteus*				1	**1**
Redfin bully	*Gobiomorphus huttoni*	1		5		**6**
Paratya shrimp	*Paratya sp.*					**173**

also kakahi

Site Ea25 Mimi River. 5 fyke nets and 12 Gee minnow traps over 80m left overnight. 31 July 2017

Species		**0+**	**Small**	**Med**	**Large**	**Total**
Longfin eel	*Anguilla dieffenbachii*				2	**2**
Giant kokopu	*Galaxias argenteus*		1			**1**
Banded kokopu	*Galaxias fasciatus*		2	5	1	**8**
Redfin bully	*Gobiomorphus huttoni*			2	5	**7**
Koura	*Paranephrops planifrons*				1	**1**
Paratya shrimp	*Paratya sp.*		5			**5**

Site E6 Mimi River. 180m fished using back pack electro-fishing. June 2017

Species		**0+**	**Small**	**Med**	**Large**	**Total**
Banded kokopu	*Galaxias fasciatus*			4		**4**
Koura	*Paranephrops planifrons*		8	1		**9**

Site E5 Mangapepeke Stream. 150m fished using backpack electro fishing. June 2017

9 small redfin bully

Site E4 Mangapepeke Stream. 120m fished using backpack electro fishing. June 2017

Species		**0+**	**Small**	**Med**	**Large**	**Total**
Longfin eel	*Anguilla dieffenbachii*			1		**1**
eel unidentfied	*Anguilla sp.*	1				**1**
Redfin bully	*Gobiomorphus huttoni*	1	8	6		**15**

Site E1 Mangapepeke Stream. 6 fine mesh fyke nets over 200m left over night. June 2017

Species		**0+**	**Small**	**Med**	**Large**	**Total**
Longfin eel	*Anguilla dieffenbachii*	**1**	1		3	**5**
Inanga	*Galaxias maculatus*		24	20	1	**45**
Redfin bully	*Gobiomorphus huttoni*			6	2	**8**
Common bully	*Gobiomorphus cotidianus*			3	4	**7**
Koura	*Paranephrops planifrons*			1		**1**
Paratya shrimp	*Paratya sp.*					**153**

also: kakahi

3.4 Aquatic macroinvertebrates

A single aquatic macroinvertebrate sample was collected from each site where SEV was undertaken (Table 2.1). The MCI scores were indicative of 'excellent' water quality in the upper reaches of the Mangapepeke Stream, but reducing to 'good' and 'fair' further downstream (site E3 and E2 respectively). The MCI scores were indicative of 'excellent' water quality at all sites in the Mimi River catchment, except the drain at site Ea28 which was in 'poor' condition and had only a very few mayfly or stonefly (probably due to the large amount of sedimentation) (Table 3.6, Appendix B).

The most numerically dominant macroinvertebrate taxa in the Mangapepeke catchment sites were:

- E2: *Paracalliope* sp. amphiod, *Austroclima* sp. mayfly, and *Potamopyrgus* snail.
- E3: *Potamopyrgus* snail, *Austroclima* sp. mayfly, and *Austrosimulium* (sandly larvae).
- E4: *Deleatidium* mayfly, *Potamopyrgus* snail, *Elmidae* and *Acroperla* stonefly.
- E5: *Potamopyrgus* snail, *Acroperla* stonefly and *Deleatidium* mayfly.
- Ea10: *Deleatidium* mayfly, *Elmidae* and *Potamopyrgus* snail.
- Ea13: *Deleatidium* and *Zephlebia* mayfly.

The most numerically dominant macroinvertebrate taxa in the Mimi catchment sites were:

- E7: Potamopyrgus snail, Zephlebia and Austroclima sp. mayfly and Paracalliope amphiod.
- E6: Potamopyrgus snail, Zephlebia and Deleatidium mayfly.
- Ea27: Austroclima sp. mayfly, Potamopyrgus snail, Zephlebia mayfly and Austrosimulium (sandly larvae).
- Ea26: Austroclima sp. mayfly, Potamopyrgus snail, and Zephlebia mayfly.
- Ea28: Ostracoda crustatea, Orthocladiinae (fly larvae), and oligochaete worms.

The freshwater mussel / kākahi (*Hyridella* sp.) and Paratya shrimp were present in the lower reaches of both Mangapepeke Stream and the Mimi River. Kōura (freshwater crayfish) were common throughout both catchments. During February sampling kōura were found in small streams above steep waterfalls (Hamill 2017).

The sampling of aquatic macroinvertebrates soon after large flood events (as occurred in early August for sites Ea10, Ea13, Ea26, Ea27 and Ea28) is not ideal as macroinvertebrate abundance and richness can be depleted. For state of environment monitoring it is recommended to wait at least two weeks following a large flood event to allow time for the stream algae and macroinvertebrate communities to recover.

Repeating sampling during a more stable period may find more species richness but is likely to make little difference to the MCI scores (which are consistent with MCI scores for the western tributary of the Mangapepeke Stream sampled in February (Hamill 2017). An increase in richness will also make only a small difference to the overall SEV score (eg perhaps an increase by 0.02 SEV points). Thus, the current samples are considered fit for purpose.

Table 3.6 – Aquatic macroinvertebrate metric for streams along the proposed route.

	Mangapepeke Stream						Mimi River				
Metric	**E2**	**E3**	**Ea10**	**Ea13**	**E4**	**E5**	**E6**	**E7**	**Ea26**	**Ea27**	**Ea28**
Number of taxa	23	31	23	23	22	16	29	27	28	15	28
Number of EPT taxa	11	15	13	12	12	9	15	19	15	12	3
% EPT taxa	48	48	57	52	55	56	52	70	54	80	11
MCI score	90	107	127	130	126	130	133	121	126	125	76
SQMCI score	5.2	5.1	6.6	7.4	6.9	5.6	6.3	5.8	6.4	7.3	3.2

EPT metrics exclude *Oxythera* sp.

3.5 Stream Ecological Valuation (SEV)

The SEV scores for the forested headwater streams in both the Mimi and Mangapepeke valleys (ie E5 and E6) were very high, in the range 0.94 to 0.92, and equate to pristine reference site conditions. The SEV scores for the small tributary in indigenous forest (site Ea13) was also high at 0.86.

Where the streams ran through pasture (sites E2, Ea27, E7) they typically had moderate SEV scores, in the range 0.52-0.58; scores were at the higher end of this range in the lower Mangapepeke Stream where more wetland vegetation remained in the pasture.

Stream sections close to the forest margin had moderately high SEV values of 0.62-0.73 (ie site Ea26, E4, Ea10). Many of the small tributaries running through pasture in both catchments had been heavily modified (straightened) and impacted by cattle pugging, this significantly lowered the SEV values (eg 0.35 at site Ea28) (see Table 3.7, and Appendix C).

An ECR was calculated for each site where the SEV was undertaken. This required estimating the improvement in SEV values from restoration work along streams restored as part of offset compensation. The average estimated improvement in SEV scores at potential offset sites was 0.23 and the area-weighted average improvement was 0.24 (Table 3.8). The sites used in the table are possible sites, but they need to be confirmed and other sites identified.

A total of 3,470m of stream was estimated to be affected by the footprint of the road, fill sites, access tracks and stream diversions. The SEV approach calculated that to offset this loss in stream values will require a compensation package that includes restoration of 8,724m^2 of stream (wetted width) (Table 3.9). The detailed site by site calculation of offset compensation required to address effects of the work's footprint is shown in Appendix C.

Using the ECR provides a way to quantify the amount of stream habitat to be restored in order to offset or compensate for a loss of habitat values. However, it should be remembered that the SEV and ECR are simply tools, and expert judgement should also be applied (eg when comparing the relative ecological values of sites being affected and sites being restored).

There remains some uncertainty about the final design. The amount of offset required to achieve 'no net loss' of stream habitat may change with modifications in the designs and better understanding of what can be achieved with stream diversions. For example, it was assumed that the large stream diversions near the tunnel (sites E5, Ea17, Ea18) would only achieve a final SEV score of 0.55. This may be overly conservative, if a final SEV score of 0.75 was achieve than the ECR would change from 2.4 to 1.1and the total calculated offset would reduce by 907m². Conversely if streams at E TL3 and E TL4 are culverted under the fill rather than diverted the amount of area required for offset would increase by 316m². It is recommended that the required offsets are recalculated once offset sites are confirmed or if there are design changes that affect streams.

Table 3.7 – Summary of SEV scores for sites survey along the proposed route, Mt Messenger. See Appendix C for full breakdown of results.

	Mangapepeke Stream						Mimi River				
Function	**E2**	**Ea10**	**Ea13**	**E3**	**E4**	**E5**	**E6**	**Ea26**	**Ea27**	**Ea28**	**E7**
Hydraulic	0.68	0.85	0.98	0.79	0.87	0.99	1	0.73	0.66	0.52	0.6
Biogeochemical	0.48	0.69	0.87	0.51	0.67	0.87	0.94	0.57	0.42	0.28	0.41
Habitat provision	0.55	0.64	0.68	0.43	0.57	0.94	0.94	0.42	0.55	0.22	0.51
Biodiversity	0.57	0.72	0.81	0.54	0.69	0.87	0.88	0.68	0.59	0.32	0.61
Overall mean SEV score (maximum value 1)	**0.57**	**0.73**	**0.86**	**0.58**	**0.72**	**0.92**	**0.94**	**0.62**	**0.54**	**0.35**	**0.52**

Table 3.8 – Estimated change in SEV scores and available stream length at potential restoration sites. Estimates for the purpose of calculating an area weighted change in SEV

site	**length (m)**	**width (m)**	**area (m^2)**	**SEVm-C**	**SEVm-P**	**SEVm-C - SEVm-P**	**description of length**
Mangapepeke Stream (east branch)							
tributaries	1041	0.43	538	0.55	0.82	0.26	Sum of tributaries excl bush and fill
ds E2	659	1.4	923	0.57	0.77	0.2	d/s E2
ds Ea10	1140	1.4	1596	0.57	0.77	0.2	E2 to Ea10 excl fill
E3	520	1.2	624	0.58	0.77	0.19	Ea13 to Ea10 excl bush and fill
E4	180	1.8	324	0.72	0.86	0.14	E4 ds to section adj. to fill
Mimi River							
Ea27	909	1.5	1364	0.54	0.77	0.23	us of E26 trib
Ea28	700	0.8	560	0.35	0.77	0.42	drain TL of valley
E7 us	400	2.1	840	0.52	0.77	0.25	section ds of E26
E7 ds	360	2.1	756	0.52	0.77	0.25	downstream to corner
Ea26	165	1.1	182	0.62	0.86	0.24	tributaries to bush/wetland
Sum	**6074**		**7705**				
Average		**1.38**		**0.55**	**0.79**	**0.24**	area weighted average = 0.24

Table 3.9 – Extent of stream affected by the Project and the area of offset to achieve 'no net loss'.

Footprint	Catchment	Impact Length (m)	Impact Area (m^2)	Offset Area (m^2)
Permanent	Mangapepeke	1100	969	4150
	Mimi	523	476	1865
Short term & diversions	Mangapepeke	1347	1464	2258
	Mimi	500	333	450
Total		3470	3242	8724

4 Assessment of effects on freshwater ecology

4.1 Overview of effects

The potential effects on freshwater ecology of culverting and diverting streams has been assessed in terms of both short-term and long-term effects. Short term effects relate to the effects limited to the construction phase including: sedimentation, direct removal of fish from the stream, short-term loss of fish passage in some areas and short term loss of stream habitat from temporary culverts.

Potential long term effects include reduced fish passage, loss of stream ecological functions and habitat, and potential effects of road stormwater on stream hydrology and water quality. These effects may potentially occur as a result of different activities including the installation of culverts, diverting streams, bridge piers that may be needed for the final footprint and any access roads required for long-term maintenance purposes.

The magnitude of effect from different types of activity is summarised in Table 3.1, using the approach described in the EcIA guidelines (see section 2.8). The table is intended as a way to focus attention on activities with the highest potential effects. The largest magnitude of effects, after mitigation, will occur from the loss of stream habitat.

The overall level of effect from habitat loss was assessed for different types of stream, using the matrix approach to combine the ecological value and the magnitude of the effect (see section 2.8). The overall level of effect from habitat loss was 'very high' for all areas – confirming the need for the Project to provide a package of offset compensation. The amount of offset compensation was calculated using the SEV method to ensure 'no net loss' of stream values (Table 3.2).[5]

The residual risk of sedimentation from earthworks was assessed as 'low' after mitigation. This mitigation is primarily in the form of management plans to ensure good practice. The overall level of effect from sedimentation is expected to be 'low' at all stream types/area. The pristine kahikatea swamp forest in the Mimi catchment will only be impacted if Erosion and Sediment Control (E&SC) measures fail. It is buffered from the Project area by a raupo reedland and rautahi swamp, and this reduces the potential effects. Erosion and occasional slips are a common feature along other stream types affected by the Project.

The overall risk from vegetation clearance will be similar to that of sedimentation, however risk of residual adverse effects is more a feature of practice and less dependent on weather conditions. Good practice mitigation will ensure that any potential effects are low.

The residual risk of permanent culverts on fish passage was assessed as 'negligible' to 'low' after mitigation. In some cases, the proposed fish passage is less than ideal but the effect is

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[5] Note that some small, shallow, intermittent streams may have lower values than used in Table 3.2 due to limited habitat for fish.

limited due to existing natural fish barriers, the small stream size and limited habitat suitable for fish upstream (Table 4.4).

Potential effects from the Project on streams is discussed in more detail in the sections below.

Table 4.1 – Magnitude of impact for activities before and after mitigation.

Effect / Activity	Magnitude no mitigation	Reason for impact without mitigation (spatial extent, duration, reversibility)	Key Mitigation	Magnitude + mitigation
Short term effects				
Direct removal of fish	Low-moderate	Direct impact to 14% and 3% of stream length of Mangapepeke East and Mimi Stream. Short term and reversable for population.	Fish Recovery Protocols	Negligible
Sedimentation from earthworks	High	Smothering of substrate downstream. Potential impact on banded and giant kōkopu. Short term impact in most cases. Potential impact greater in swamp forest.	Erosion and Sediment Control Plan, monitor	Low
Vegetation clearance	High	Poor practice has potential to deoxygenate water downstream. Reversible, but persists until woodchip removed from stream.	Vegetation Clearance Management Plan	Low
Concrete	Low	Small area, distant from waterways and short duration = low risk of spills.	E&S Control of water	Negligible
Short term fish passage	Low	Potential loss of recruitment to upper Mangapepeke for a season. Reversible.	Design for passage	Negligible
Short term habitat loss	Moderate	Short term loss of stream habitat and reduced functions. Restored following construction.	Offset residual impact as per SEV	Moderate (requires offset)
Water takes	Low	Short term and small magnitude. Possible impact downstream.	Intake screened, take volume <10% of stream flow	Negligible
Long term effects				
Fish passage	High	Long term fish passage lost to about 50% and 8% of Mangapepeke East and Mimi length. Reversible.	Design for fish passage	Negligible to Low
Loss of stream habitat	High	Large amounts of high quality stream habitat lost to piping. Reduced stream functions. Difficult to reverse.	Stream diversions based on Ecological Design Principles, Stream Restoration Plan, Offset as per SEV	High (requires offset)
Stormwater	Negligible	Very small change in impervious surface from road. No change in vehicle volumes from Project.	Swales, treatment wetlands	Negligible

The proportion of catchment is based on the length upstream of the work area.

Table 4.2 – Magnitude of effect from stream loss, ecological values, and overall effect for different stream types (after mitigation but before any offset).

Stream type / area	Ecological value	Reason for value	Magnitude of effect	Overall Effect	Offset
Steep, forested	High	Presence of At-risk declining fish species (longfin eel, redfin bully). High SEV values and Ecological Integrity	High	Very high	Offset for 'no net loss'
Low gradient, rough pasture	High	Presence At-risk declining fish species (inanga, longfin eel, giant kōkopu, redfin bully, kākahi). Moderate SEV values	High	Very high	Offset for 'no net loss'
Kahikatea swamp forest remnant (Mangapepeke valley)	High	Presence At-risk declining fish species (inanga, longfin eel, giant kōkopu, redfin bully, kākahi). High SEV values.	High	Very high	Offset for 'no net loss'

Table 4.3 – Magnitude of effect from sedimentation (after mitigation), ecological values, and overall effect for different stream types.

Stream type / area	Ecological value	Reason for value	Magnitude of effect	Overall Effect	Key mitigation
Steep, forested	High	Presence of At-risk declining fish species (longfin eel, redfin bully). High SEV values and Ecological Integrity.	Low	Low	E&S Control
Low gradient, rough pasture	High	Presence At-risk declining fish species (inanga, longfin eel, giant kōkopu, redfin bully, kākahi). Moderate SEV values	Low	Low	E&S Control
Kahikatea swamp forest remnant (Mangapepeke valley)	High	Presence At-risk declining fish species (inanga, longfin eel, giant kōkopu, redfin bully, kākahi). High SEV values.	Low	Low	E&S Control
Kahikatea swamp forest (Mimi valley) *	Very High	Presence At-risk declining fish species (longfin eel, giant kōkopu, redfin bully, kākahi). High SEV scores; high Ecological Integrity; representitive and rare.	Negligible to Low *	Low to Moderate	E&S Control, monitor

* The pristine kahikatea swamp forest in the Mimi catchment will only be impacted if E&S Control measures severely fail. It is buffered from the Project area by a raupo reedland and rautahi swamp.

Table 4.4 – Magnitude of effect from permanent culverts (after mitigation), ecological values, and overall effect for different culvert/stream types.

Stream type / area	Ecological value	Reason for value	Magnitude of effect	Overall Effect	Key mitigation
Low gradient culvert on low gradient streams	High	Presence of At-risk declining fish species (inanga, longfin eel, giant kōkopu, redfin bully, kākahi). Moderate SEV values	Negligible	Low	Invert below stream bed. Baffles
Very steep culvert on small, steep forested stream	High to Moderate	Small size and shallow water means little fish habitat, but some At-risk declining fish (longfin eel, redfin bully) may be present. Climbers. High SEV values.	Low	Low	Baffles and spat rope. Outlet design
Scruffy dome on steep, intermittent streams	Moderate	Little if any fish habitat due to very small stream size. Intermittent, but high SEV values.	Low	Low	Spat rope at inlet

4.2 Short term construction effects

4.2.1 Direct effects on fish and Fish Recovery Protocols

Filling-in stream channels and removing vegetation and sediment from streams poses a risk to native freshwater fish of mortality or injury. The magnitude of risk is dictated by the nature of the activity, the area of the stream disturbed, density of fish present in the stream, and the ability of fish to escape the disturbance. The rarity of the fish, ie its conservation status, is also relevant when assessing the potential level of effect.

The activities that can cause direct removal of fish include installing culverts and stream diversions. In the absence of any fish recovery there is a risk of direct removal, stranding or injury. Work in low gradient streams (eg culvert 9 and some access tracks) could affect species including inanga, longfin eel, redfin bully, giant kōkopu, kōura and kākahi. Work in steeper gradient streams (eg culverts 14, 15 and 21) are more likely to affect species including banded kōkopu, longfin eel, redfin bully and kōura, which can access these steeper catchments.

Ephemeral and intermittent streams with steep gradients along the route have limited fish habitat because of their small size and shallow water. Kōura may be present at these sites but other fish are likely to be absent or in low abundance (as found when intermittent tributaries to the Mimi River were electro-fished).

4.2.1.1 Mitigation

The direct effect of earthworks on large stream fauna (ie fish, kōura and kākahi) can be considerably minimised and mitigated by implementing Fish Recovery Protocols prior to draining, diverting or excavating streams. These should be applied in a risk based way, so that more intensive effort is applied to streams that are more likely to have 'At-Risk' species present, or high abundance of fish due to the type of habitat present.

Fish recovery is seldom 100% effective and techniques likely electro-fishing, netting and trapping have inherent risk of fish mortality and injury. These risks can be reduced by the choice of equipment and using good techniques, but cannot be eliminated. The fish recovery technique that has the least risk to fish and is often most effective is allowing the voluntary escape of fish as an area is dewatered. But this is not possible in every situation and often other fish recovery techniques also need to be used.

The purpose of the Fish Recovery Protocols (FRP) is to describe the methods that will be undertaken to minimise direct effects of construction on fish, kōura and kākahi (freshwater mussels) in waterways affected by the Project. It should cover procedures and locations for:

- recovery of fish prior to instream works,
- rescue of fish from any spoil,
- relocation of fish, and
- reporting.

4.2.2 Potential sedimentation from earthworks and construction

4.2.2.1 General effects of sediment in streams

The primary ecological concern regarding sediment in discharges is not so much the change in clarity of water but instead deposition of sediment on the stream beds. Most fish species, with the exception of very sensitive species such as banded kōkopu, are tolerant of high levels of suspended sediment, but many taxa are affected by a combination of other environmental changes associated with high loadings of suspended solids.

Banded kōkopu reduce feeding and show avoidance behaviour when water turbidity is over 25 Nephelometric Turbidity Units (NTU) (Richardson et al. 2001), but numerous studies have shown that sublethal turbidity have little direct effect on most other fish species (Rowe et al.2002). Rowe et al. (2002) found that the supposedly 'sensitive' invertebrate and fish taxa were tolerant of very high levels of turbidity (over 24 hours), and even repeated exposures to 1000 NTU had no adverse effects on their survival. They concluded that '*their absence from urbanised catchments and their relative scarcity in turbid rivers and streams is not caused by turbidity per se, but most likely reflects a combination of other environmental changes associated with high loadings of suspended solids*.'

The main ways which suspended sediment affects aquatic macroinvertebrate abundance and diversity is:

- smothering and abrading;
- deposition reducing their periphyton food supply or quality; and
- deposition reducing available interstitial habitat.

Moreover, sediment deposition can alter substrate composition and change substrate suitability for some taxa (Wood and Armitage 1997). These effects persist long after a rain event has stopped.

4.2.2.2 Sediment in streams around Mt Messenger

Fine sediment is a typical feature of the substrate in streams around Mt Messenger. Low gradient sections of the Mangapepeke Stream and Mimi River were predominantly silt (eg 66% silt at site E7, >95% silt at sites E2 and E3). As streams become steeper, gravels and cobbles become more common but even steep forested sections (eg E4, E5, E6, Ea13) have a relatively high cover of fine sediment considering the low pressures in the catchment (see Table 3.2).

The reason for the relatively high sediment cover in streams is the papa mudstone geology. This is a soft rock and the gravel and cobbles are readily crushed to silt by hand. Small slips were common even in bush catchments and stream bank erosion is common in areas of pasture. High sediment loads appear to be a natural feature of these streams, but in the absence of mitigation measures land disturbance can easily cause accelerated erosion and sedimentation (see Figure 4.2).

The stream most likely to be sensitive to additional sedimentation is the tributary to the Mimi River at E6 and the downstream swamp forest. The substrate in this section of stream is predominantly gravels and small cobbles. Downstream of site E6 is a pristine example of kahikatea swamp maire swamp forest (Figure 4.1). Although the streams in the swamp forest have fine sediment, their deep and often narrow morphology could be changed by excessive sedimentation. Also, banded kōkopu, which is more sensitive to high turbidity than most native fish, were found at sites E6 and the swamp forest streams.

The kahikatea swamp forest is buffered by a raupo (*Typha orientalis*) reedland and rautahi (*Carex geminata*) swamp. This naturally filters sediment entering the swamp forest during floods. Nevertheless, the high value of the swamp forest and the extent of work occurring upstream means that extra care should be taken with Erosion and Sediment Control (E&SC) upstream of the swamp forest. If an extreme event causes a failure of E&SC measures and significant sediment discharge occurs, then monitoring should be undertaken to confirm if sedimentation affected the kahikatea swamp forest (e.g. fish, channel morphology, vegetation). In the unlikely event that the Project does cause adverse effects within the kahikatea swamp forest then further biodiversity offsets may be required in addition to what is described in this report. This is also discussed in Technical Report 7a (Volume 3 of the AEE).

Other sections where particular care will be needed with E&SC is bridge works are Ea20 and the fill section at Ea21 – both upstream of kahikatea swamp maire swamp forest. Care should also be taken upstream of E4 because the Mangapepeke Stream substrate at this point is still dominated by gravels and cobbles.

4.2.2.3 Mitigation

Accelerated erosion and sedimentation can be minimised and mitigated by ensuring good Erosion and Sediment Control (E&SC) practices. The approach to E&SC for various activities is discussed in the Construction Water Assessment Report (Technical Report 14, Volume 3 of the AEE). This includes measures to avoid excessive reduction of pH caused by any flocculants used in the settling ponds. Some sediment is likely to be discharged from areas of works during rainfall events, but will generally occur when the streams are under higher flows and receiving sediment from other sources in the catchment.

There will also be a period during the early stages of construction when access tracks will be cleared in order to bring plant to the sites where long-term sediment control ponds will be constructed. During this period, there is greater risk of sediment release. The Project will manage this risk by working (to the extent possible) only in the dry and not adjacent to watercourses, minimising works areas, and installing "interim" ponds and traps (which will be to lower than normal design standard for long-term sediment control ponds).

Monitoring can be undertaken to assess the effectiveness of E&SC and whether there is any excessive sedimentation of waterways during construction. After implementing mitigation, the overall level of effect from sedimentation is expected to be 'low' for all stream types/area (Table 4.3).

Figure 4.1 – Mimi River tributary flowing through the kahikatea swamp forest (site Ea25).

Figure 4.2 – Some sources of sediment to streams around Mt Messenger. Top: a landslide in a tributary downstream of the Project's route (38.898097°, 174.576161°). Middle: sedimentation in a forested headwater of Mangapepeke Stream west branch (site N7, Hamill)

4.2.3 Potential water quality effects from vegetation clearance

Vegetation clearance can have a number of potential effects on nearby streams. Felling and removal of trees can expose soil, make it more prone to erosion and cause sedimentation, the effects of which are discussed above. In addition, the accumulation or storage of sawdust, chip or mulch near or over waterways can cause serious water quality effects if it occurs.

The bulk storage of woodchip and wood residue can produce leachate with a high Biological Oxygen Demand (BOD) as well as organic dissolved organic matter that promotes the growth of heterotrophic organisms (eg bacterial mats and 'sewage fungus'). Both the BOD load and heterotrophic growths deplete dissolved oxygen from the water and sediments, with consequent adverse effects on aquatic life.

Leachate from storage of wood residue can also leach potentially toxic compounds in the form of tannins, phenols, and resin acids. The toxicity of these compounds tends to reduce with increasing pH (Samis et al. 1999).

The effect on streams of woodchip residue from vegetation clearance depends on the amount stored, proximity to waterways, size of the waterways and mitigation. Moderate amounts of woodchip beside a stream has negligible effects and is commonly used to positive effect as part of restoration. Similarly, small amounts of woodchip entering a stream will have negligible adverse effects. However, in situations where vegetation clearance causes piles of woodchip to cover a waterway, the effect on the aquatic life can be devastating, with large loss of invertebrate and fish life downstream until sufficient reaeration or dilution occurs.

The Project requires a large amount of vegetation clearance. In the absence of good practice there would be a high potential risk of vegetation clearance causing adverse water quality effects, particularly in small waterways with a forest catchment. Fortunately, the adverse effect of vegetation clearance and wood residue can be avoided and minimised by ensuring good management practice.

4.2.3.1 Mitigation

A Vegetation Clearance Protocol should be prepared, which includes procedures for minimising the area and duration of soil exposure from vegetation clearance, minimising the volume of vegetation to be mulched, locating wood residue piles with an appropriate separation distance from any waterways, and minimising potential leachate from these piles.

The protocol should seek to minimise the amount of wood that is mulched and set it aside for later use in rehabilitating the site and streams. A risk based approach is appropriate for managing mulch taking into account the size of the stockpile, proximity to watercourses, topography and the duration of stockpiling. It should be noted that coarse woody debris is an important part of stream habitat, while it is excessive amounts of fine material like mulch that can cause adverse effects to watercourses.

If it is not practical to prevent piles of wood chip entering a stream that will eventually be culverted, then a culvert should be installed prior to the vegetation clearance to avoid potential effects on water quality.

If vegetation clearance adjacent to streams occurs prior to fish recovery then care is needed to ensure direct effects on the stream are minimal and logs and branches do not prevent access to the stream.

4.2.4 Potential water quality effects from concrete

Water that comes in contact with unset concrete, concrete fines, concrete dust or concrete washings can become highly alkaline. If this runoff enters receiving waters untreated it can have adverse effects on aquatic life. There is a wide range of sensitivities of freshwater fish and invertebrates to pH, but most aquatic invertebrates and fish are tolerant to pH in the range of 6 – 9, and this range was proposed as a possible national bottom line (Davies-Colley et al. 2013). Causing pH to extend outside this range has the potential to adversely affect aquatic ecosystems and is likely to change some geochemical processes. Many native fish species show avoidance of pH values below 6.5 (West et al. 1997). The ANZECC (2000) guidelines recommend that discharges causing unnatural pH changes of more than 0.5 units should be investigated.

Concrete will be poured in a number of locations along the route, but particularly near the tunnel and for the bridge supports near site Ea20. The risk of concrete affecting stream water quality is low because the areas affected are limited in scale, are not directly in water and the potential effect of concrete on stream water quality will be minimised and mitigated by capturing and treating any runoff. This is described in the Construction Water Assessment Report (Technical Report 14, Volume 3 of the AEE).

4.2.5 Short term fish passage

4.2.5.1 Fish migration

Many New Zealand fish are diadromous and need to migrate between the freshwater and the sea in order to complete their life-cycle. Some populations can become landlocked but often mimic diadromous behaviour, but in freshwater. Maintaining fish passage upstream and downstream is important to allow fish populations to be sustainable and recruit. The timing of migration is often associated with environmental conditions such as temperature, rainfall, stream flow or tides. Upstream migrations may also be delayed by large floods.

The timing of fish migration and spawning is shown as a calendar in MPI (2015). The upstream migration period for migratory fish present in the Mimi River and Mangapepeke Stream span most of the year (August to April inclusive) however, for most of the species the peak migration occurs in spring to early summer (August to December). The period of peak upstream migration of each migratory species is: banded kōkopu (September to October), giant kōkopu (November), inanga (August to November), redfin bully (November to March[6]), longfin eel (December to March). Excluding works during a migration period can be

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[6] Hamer (2007) reports the peak upstream migration period for redfin bully as November to December.

used to mitigate effects, but is often not practical when dealing with multiple species. Furthermore, it is not necessary if alternative mitigation strategies are used. These are discussed below.

4.2.5.2 Potential effects of the Project

Upstream fish passage could potentially be restricted for a short period during construction when culverts are installed and water is flowing through any temporary diversion pipes. If restrictions to fish passage occur for only a few days the adverse effect on fish communities will be negligible. However, large amounts of fill are required on either side of the tunnel (ie upstream of sites E5 and E6), and the process of filling and creating a clean water diversion may take several months. A temporary culvert will be installed to carry water under the fill until the clean water diversion is created on top of the fill and permanent culverts installed. This could adversely impact one season of recruitment if it occurs during an upstream migration period and the temporary culvert does not allow adequate fish passage. The adverse effect will be greater for the upper Mangapepeke Stream because there is a larger upstream catchment beyond the area of works with more potential fish habitat.

The magnitude of effect of restricting upstream migration to about 50ha of catchment for a season is likely to be ‘low’. Using the EcIA approach a ‘low’ magnitude of effect on a system with ‘high’ ecological value results in a ‘low’ overall effect. Nevertheless, mitigation measures can be taken to reduce this effect.

Installing new culverts and extending existing culverts may be required for access tracks. Some of these culverts will be removed at the end of the construction period. In the absence of fish passage, they could restrict migration and recruitment for several years. This potential effect should be avoided by installing the culverts required for access tracks so as to allow for fish passage where fish migration and recruitment is identified.

4.2.5.3 Mitigation

Measures should be implemented to mitigate the effects of reduced fish passage during the construction period from temporary culverts used in large areas of fill near the tunnel. Ways to mitigate this short term effect include trap and transfer or placing spat rope through the culvert. Spat rope can facilitate the upstream migration of juvenile climbing species likely to be present in the stream, ie banded kōkopu, longfin eel and redfin eel. Waterfalls form a natural barrier to non-climbing fish species in these sections, and spat rope (as opposed to baffles) is an adequate approach to address a short-term effect.

4.2.6 Short term loss of stream habitat

Streams will need to be diverted or culverted at multiple locations for the period of construction, but will be restored to a stream at the completion of works. These crossings will be removed after the end of the construction period, so their effect on stream habitat will be short-term. Nevertheless, there will be a loss of stream functions during the construction period. The SEV values of the lower Mangapepeke Stream is currently about 0.57 (moderate), in the sections being piped the SEV will reduce to about 0.23 while the pipes are in place. At the end of the construction period the pipes associated with temporary access tracks will be removed and the stream channel and margin restored to their original (or better) condition.

The effect of access tracks on the Mangapepeke Stream has been minimised by following the existing access track where possible and rationalising stream crossings. Their effect will also be mitigated by ensuring fish passage as discussed above. However, the short-term loss of stream values requires offset compensation.

The amount of offset required to achieve 'no net loss' of stream habitat due to short-term effects is included within the overall compensation calculations (see discussed below).

4.2.7 Water takes for dust suppression

4.2.7.1 Background on water takes

Water takes can potentially affect aquatic life by changing the available habitat (eg wetted width, depth and velocity) and by changing physio-chemical water quality (eg water temperature, dissolved oxygen, and nutrients). In some cases, the water intake itself has potential to entrain and strand fish where intake velocities are high and /or barriers are not used.

The risk of the abstraction causing adverse effects depends largely on the stream flow relative to the take, its duration and frequency, the stream morphology and the species present. A stream with riparian shade, a U-shaped morphology and deep pools is less sensitive to water takes than unshaded streams with a wide, shallow morphology and few pools.

The draft guidelines for ecological flows (Beca 2008) notes that "*an abstraction of up to 10% of the mean annual low flow (MALF) is barely measurable and therefore unlikely to result in adverse effects on the stream. Abstraction of up to 20% of MALF is unlikely to result in significant biological effects in lake- or spring-fed streams or in streams with frequent floods and freshes, such as those draining mountainous regions exposed to the prevailing westerly winds*" (Beca 2008). One way to protect flows is to base it on historical flow events (eg setting a minimum low flow as 90% of the 7-day MALF); another is to adjust the total amount of water to be extracted from the river with flow, such as to allow the abstraction of 10% of the flow at any one time.

4.2.7.2 Effects of water takes for dust suppression

The Project is seeking two water takes for the purpose of dust suppression. These are:

- up to 150m^3/day from the Mimi River near the southern extent of the Project area with a catchment area of about 978ha; and
- up to 300m^3/day from the Mangapepeke Stream. The location will be near the northern extent of the designation either about 50m upstream of the confluence with the west branch (catchment area of about 330ha) or just downstream of this confluence (catchment area to 683ha).

There is no reliable hydrological information near the Project area that can be used to confidently estimate low flows in the Mimi River or Mangapepeke Stream. In the absence of this information, it is proposed that water takes are restricted to no more than 10% of the flow at the time of the take.

For practical purposes it is proposed to use water level as a proxy for flow; thus a condition might read, *"...no more than 20% change in water depth, measured on a staff gauge located in a run and measured at a time when unaffected by the take*". Water depth in runs should provide a reasonable proxy for flow in the lower Mangapepeke Stream and Mimi River because the stream morphology is U-shaped and the gradient is relatively flat. Furthermore, in these types of streams, water depth is more directly relevant to effects on fish habitat than flow.

The water intakes will need to be appropriately designed to exclude fish. In particular the screen mesh size will need to be less than 3mm (side of square) and the surface area sufficiently large so that water velocities through the intake are less than 0.12 m/s (see Jamieson et al. 2007).

4.3 Long term / permanent effects

4.3.1 Fish passage

4.3.1.1 The need for fish passage

Maintaining fish passage upstream and downstream is important to allow upstream fish populations to be sustainable. Most fish in the catchments are diadromous, requiring migration to and from the sea as part of their life cycle. Kōura are not diadromous but maintaining passage for kōura is still important to avoid isolated and fragmented populations.

Near the headwaters of both catchments, waterfalls and cascades form natural barriers to non-climbing fish species like inanga. However, climbing fish and invertebrate species such as longfin eel, banded kōkopu, redfin bully and kōura are often found above waterfalls (eg Mangapepeke Stream west branch in Hamill 2017).

Poor culvert design can restrict fish migration. Often this occurs as a result of culverts being perched, the water flowing too fast, too shallow, or as laminar flow with insufficient roughness. This becomes a more significant issue when fish access is restricted from larger upstream catchments.

4.3.1.2 Effects of the Project

The Project involves installing 21 new culverts. This may involve replacing or extending existing culverts. Most of the culverts will be about 25 to 40m long but near the headwaters the proposed culverts are about 100m to 210m long (eg at sites Ea16, Ea17 and Ea19) (Table 2.1, Figure 4.3).

12 of the 21 culverts will have a grade of about 1% or less (1:100). In most cases fish passage will be provided through these by ensuring the culvert invert is set below the stream bed and installing baffles at regular intervals (eg one every 10m for flexible iris baffles). Culvert 15 (site Ea16) has a low gradient (1%) but will require particular attention to

ensure good fish passage through it because it will be long (210m) and has a reasonably large upstream catchment (ca. 50 ha).

Four culverts will have a moderately steep grade of about 3 to 4% (1:30 to 1:25) (culverts 5, 7, 8, and 16). These culverts will have baffles to ensure fish passage with baffle spacing of about one every 2.5m for flexible iris baffles.

The culvert proposed for site Ea13 (culvert 12) has a 7% grade (ca. 1:14). This is steep but fish passage can still be provided by use of closely spaced baffles (eg every 1.4m spacing).

Four culverts will have very steep grades of 14% to 17% (ca. 1:7 to 1:6) (sites Ea12, Ea14, Ea15, and Ea21 at culvert id 11, 13, 14, and 17 respectively). One of these culverts (site Ea15) is long (117m). In order to provide fish passage through these baffles (eg iris baffles) would need to be very closely spaced (eg <1m). Spat rope may need to be used in combination with the baffles.

All of these waterways with steep gradient culverts have small catchments (1.6ha, 1.7ha, 5ha and 3ha respectively), all except site Ea12 have existing fish barriers in the form of large waterfalls (sites Ea14 and Ea15), or are perched culvert under the existing road (site Ea21) (Figure 4.4). Relying on spat rope to provide fish passage on new built culverts is not ideal, but is adequate when used with baffles and in the context of the limited upstream habitat and existing barriers.

Fish passage is not being provided for Culvert 2, 10 and 13 (sites Ea2, Ea11, and Ea14 respectively). These will be downstream of cut-faces and the inlet will be manholes with a scruffy dome lid. These all have very small catchments (<2ha) and are likely to be seasonally intermittent or ephemeral. Fish passage to sites Ea1 and Ea2 is currently restricted by an existing manhole (Figure 4.4), and fish passage to site Ea14 is restricted by a 12m high waterfall. All of these small waterways have a steep grade and shallow water that offers little, if any, fish habitat upstream of the alignment. Kōura may be present but probably low abundance due to the shallow water. Kōura are strong climbers and passage for them could be provided by hanging spat rope over conveyer-belt type material through the manhole. The abundance or absence of fish or koura in these particular intermittent streams should be confirmed to assist with decision of using spat rope.

The overall residual effect of the Project on fish passage, after mitigation, is expected to be 'negligible' to 'low' for those designed as steep culverts and scruffy domes. In some cases, the proposed fish passage is less than ideal but the impact is limited due to existing fish barriers (waterfalls), the small stream size and limited habitat suitable for fish upstream (Table 4.4). Options for designing fish passage through culverts are discussed below.

4.3.1.3 Fish passage provision options

Bridges and arch culverts have less effect on streams than pipe culverts and ensures reliable fish passage. However, these options are not always practicable. The next best option for ensuring good fish passage for low gradient streams, is to over-size the culvert by about 10 to 20%, place it with a relatively flat gradient (ie less than 0.5%), and ensure the downstream invert is below the level of the stream bed (about 20% of culvert diameter). This allows a natural bed material to form within the culvert and helps ensure sufficient water depth.

If there is a culvert apron it should be constructed to retain water to a depth of about 100mm (or more). This can be done by inserting the culvert invert below the streambed and/or constructing a pool and low rock weir (eg V-vane) downstream of the culvert and apron (Roisgen 2006, NZ Fish Passage Advisory Group 2015). Good outlet design can not only maintain fish passage but also provide habitat by retaining water depth, pools and diverse hydrology.

Installing habitat devices in the low gradient culverts on the larger streams (eg >25 ha) would help mitigate their effect on fish habitat. These are constructed habitat within stream banks that provides cover for eel and other fish. There is little value in using fish habitat devices in culverts associated with very small waterways due to the low water levels. Habitat devices can take multiple forms. Fish tunnel houses can be bolted to the culvert base or sides; or 'tuna town houses' can be installed in the banks of outlet structures.

Culverts with steeper grades will require baffles to slow water velocity and allow for fish passage. The baffles also help retain water depth within the culvert during base flow conditions. Spat rope can be a valuable fish passage solution for climbing species where baffles are not practical, e.g. in very steep gradient culverts where other solutions are not practicable. Guidance for their use is provided by David et al. (2014).

There are many options for baffle design. Cuboid spoiler type baffles are well proven for providing fish passage for grades up to 2-3%. They need to be placed along the length of the culvert (Boubée et al. 2000). Flexible iris baffles are also effective at providing fish passage when appropriately spaced and have additional benefits of being very robust, holding back water and creating micro habitats.

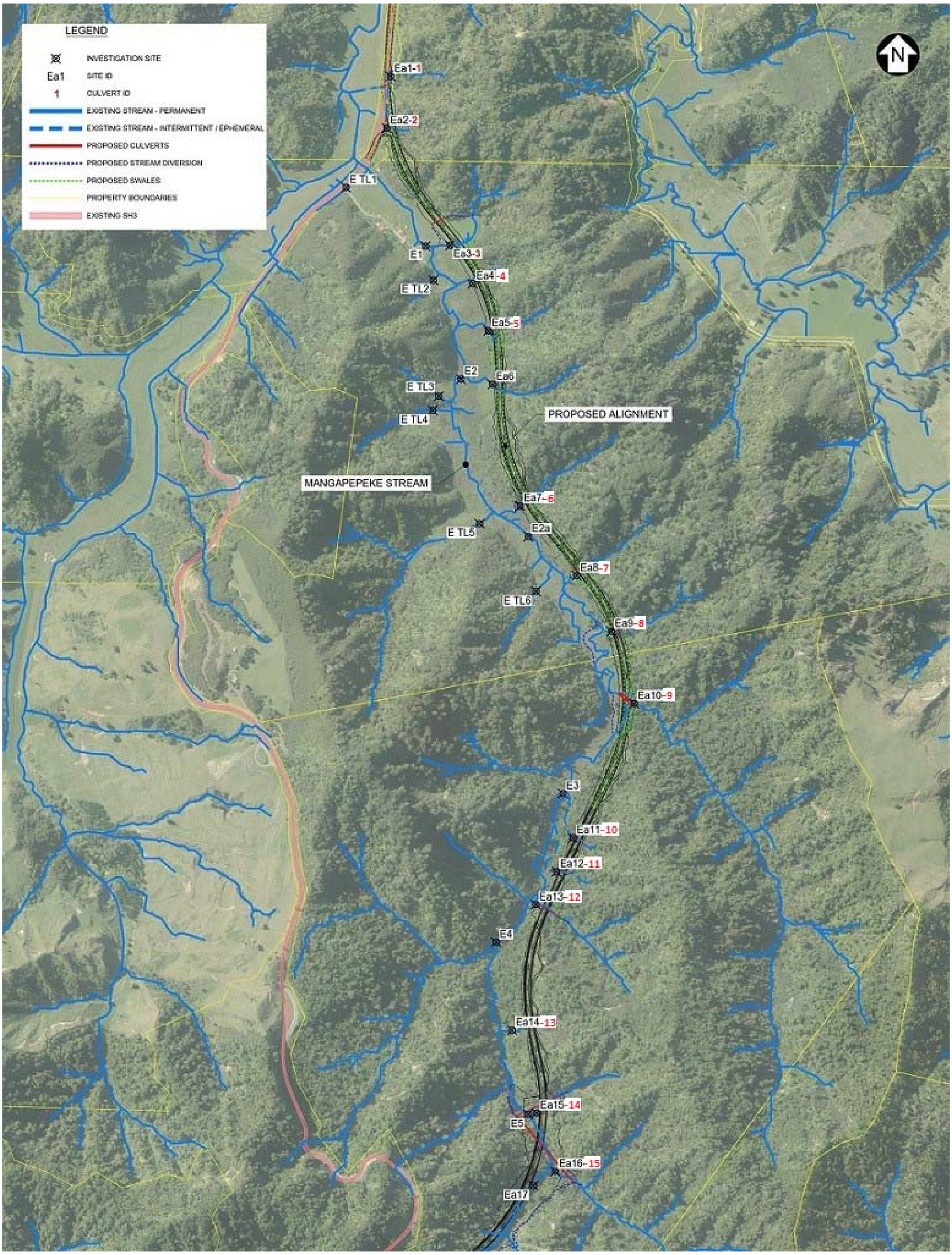

Figure 4.3a - Location of culverts on the Project, Mangapepeke Stream catchment.

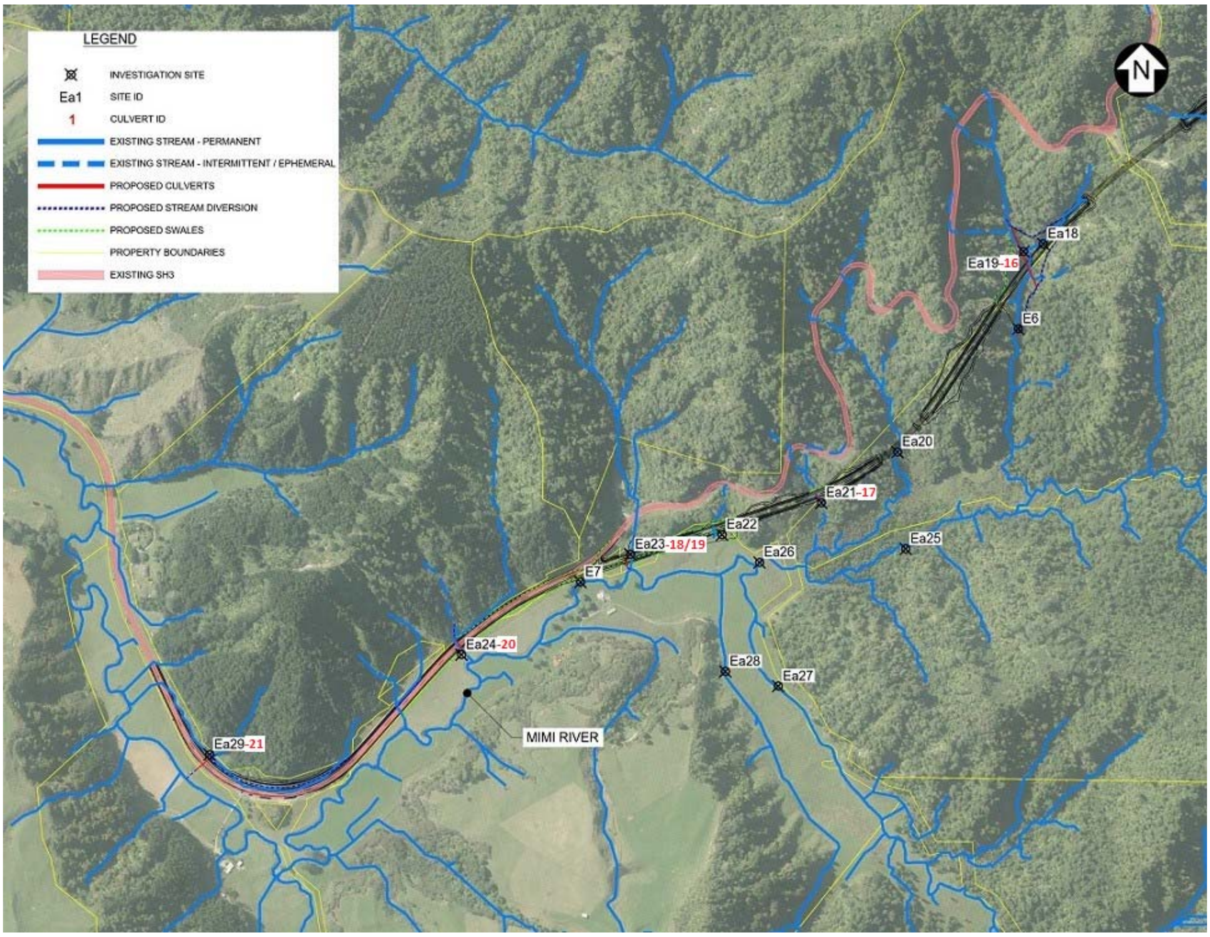

Figure 4.3b - Location of culverts on the Project, Mimi River catchment.

Figure 4.4 – Fish barriers on small intermittent streams from the current SH3. Site Ea1/Ea2 (top) site Ea21 (bottom) (1 August 2017). Limited fish habitat upstream of these barriers reduces their overall effect on fish populations.

4.3.2 Loss of stream habitat and functions

The Project will require installing or extending culverts on 21 waterways, diverting three small, intermittent waterways to swales and three larger stream diversions (sites Ea10, E5, Ea17/18 and E7). This will result in the loss of stream ecological function and values.

The amount of stream affected by the permanent footprint of the Project is 3,470m of length and 3,242m^2 of stream habitat. About two thirds of the affected stream length is in the Mangapepeke catchment and one third in the Mimi catchment. About half the affected stream length is in pristine condition (an SEV score >0.9), and most (84% by length and 63% by count) of the affected streams are permanently flowing, perennial streams[7] (Table 4.5).

The effect can be mitigated by ensuring fish passage and use of habitat devices in and around the culverts, nevertheless, this is a large scale, semi-permanent loss of moderate to high quality stream habitat, functions and values. It constitutes a very high adverse effect that requires offset as part of a compensation package.

The SEV approach was used to calculate the amount of offset compensation required for the loss of stream values. This accounted for the loss of potential stream values from the permanent footprint of the road and fill areas, as well as short-term loss from access tracks, stormwater ponds or stream diversions. It incorporated a multiplier to account for time lags associated with establishing riparian vegetation, and by using stream area placed more weight on the loss of larger streams which, to some extent, provide more habitat for fish than very small or intermittent streams.

The SEV approach calculated that 8,724m^2 of stream area is required for restoration in order to offset or compensate for the loss in stream values. This restoration is in addition to creating stream diversions with SEV values of moderate to high ecological condition. This restoration could consist of riparian planting to improve the current stream condition.

In calculating offset compensation, realistic potential outcomes for restored streams using good design and implementation was assumed. It is important that ecological design principles are used in the final design and implement. Ecological Design Principles should be developed to guide the refinement of stream diversion designs. A Stream Restoration Plan will be developed as part of the Ecology and Landscape Management Plan (ELMP) to guide restoration and improve certainty that the assumed outcomes will be achieved.

There remains some uncertainty about the final design. The amount of offset required to achieve 'no net loss' of stream habitat may change with modifications in the designs and better understanding of what can be achieved with stream diversions. For example, ensuring higher quality stream diversions near the tunnel would result in less impact, lower ECR values and less offset being required. The amount of offset required was based on the designs available in the AEE drawing set; the amount of offset to achieve 'no net loss' of stream habitat should be recalculated if there are substantive changes to designs that affect streams.

[7] Perennial streams were defined for this purpose as streams with a catchment area >5ha.

Table 4.5 – Amount of stream affected by the road footprint differentiated according to catchment and current SEV value (SEV scores >0.9 are pristine).

	Current SEV score				
Catchment	>0.9	0.7 - 0.9	0.5 -0.7	<0.5	**Total**
Mangapepeke	887	671	824	65	2447
Mimi	505	248	40	230	1023
Total length (m)	1392	919	864	295	3470
Total area (m^2)	1871	737	505	129	3242
% length permanent	100%	78%	63%	83%	84%
% area permanent	100%	92%	78%	84%	94%

4.3.3 Potential effects of stormwater runoff

4.3.3.1 Hydrology and morphology

Stormwater discharges can alter stream hydrology. An increase in impervious surfaces from roads and urbanisation can increase flood peaks and volume causing them to be more 'flashy' than natural streams. As a result, urban streams are often deeper and wider than natural streams, become simpler and uniform, and have more fine sediment on the beds. This can result in less diversity and abundance of macroinvertebrates and fish in the stream (Storey et al. 2013, Walsh et al. 2005).

The potential effects of stormwater on hydrology can be minimised by reducing the amount of impermeable area, and by using treatment devices that enhance infiltration and flow detention (Storey et al. 2013).

4.3.3.2 Water quality

Contaminants of particular concern in road runoff include sediments, metals (especially copper and zinc) and hydrocarbon compounds. Copper and zinc are important constituents in brake linings and tyres respectively. Braking and tyre wear results in the emission of brake pad and tyre debris, containing these metals, to the road surface. Hydrocarbon compounds are emitted to the road surface from oil, grease and fuel leakages and spills, and from exhaust emissions. Metals and hydrocarbons can enter stormwater attached to sediment, in a dissolved form, or (in the case of hydrocarbons) floating on top of the road runoff.

The potential water quality effects of road runoff can be mitigated by using treatment devices such as swales and treatment wetlands. Swales can result in average load reductions for total suspended solids (TSS), total copper and total zinc of 0.6, 0.8 and 0.8 respectively (Moores et al. 2010). Stormwater treatment wetland can result in average load reduction factors for total suspended solids (TSS), total copper and total zinc of 0.7, 0.5 and 0.65 respectively. Vegetated stormwater ponds are less effective at removing metals than swales because metals often occur in a dissolved state (Moores et al. 2009).

4.3.3.3 Thermal pollution

Water temperature has a strong influence on the distribution of aquatic biota. It directly affects metabolism and indirectly affects biota by influencing pH, dissolved oxygen and algae growth. Richardson et al. (1994) assessed the upper and preferred temperatures of eight NZ fish species.

Shortfin eel was the species found to be most tolerant of warm water (preferring 26.9°C), whereas banded kōkopu, inanga and smelt preferred cooler water (preferring 16.1, 16.1, and 18.7 °C respectively). Olsen et al (2012) recommended maximum water temperatures to protect the most sensitive native species of 20°C for upland stream and 25°C for lowland streams. Temperature tolerance of fish is affected by the acclimatisation temperature, and a rapid increase in temperature can cause thermal shock (Herb et al. 2007).

Thermal pollution from stormwater can be reduced by reducing the amount of impermeable area, maximising infiltration (eg grass swales and infiltration trenches), using vegetated treatment wetlands and increasing shading (of the stream or treatment devices). Swale vegetation cools the first flush of stormwater. Vegetated treatment wetlands can mitigate thermal pollution by providing shading, evapotranspiration and infiltration. Wetlands also mitigate the thermal load by capturing small rain events (Young et al. 2013).

4.3.3.4 Effects of stormwater from the Project

The effect of stormwater on the water quality and hydrology of a receiving water largely depends on the relative volume of stormwater compared to the stream, contaminant sources in the catchment, and type of stormwater treatment.

The Project will increase the amount of impervious surface area in both the Mangapepeke Stream and Mimi River catchments, but in absolute terms the amount of impervious area will remain very low. Where stormwater ponds are planned in the lower Mangapepeke Stream the impervious surface will be about 2.4% of the catchment; while in the Mimi River at site Ea7 it will be 0.7% of the catchment after the Project completion (Table 4.6). This amount of impervious surface is very low in the context of an SEV assessment. Traffic volumes over the road are low-moderate, with annual average daily traffic volumes currently 2,364 increasing to 3,798 by 2037.

Stormwater from the road will be treated in swales and treatment wetlands situated near site E1 at the northern end and site E7 at the southern end of the Project extent (see stormwater design description in Volume 1 of the AEE, and the Drainage Layout drawings in Volume 2 of the AEE). These will be vegetated wetlands with a banded design to provide stormwater detainment and treatment.

The combination of the Project having a small impervious footprint relative to the catchment, stormwater treatment devices and low to moderate traffic volumes will result in the Project having only a small effect on hydrology, thermal pollution and water quality. In fact, there may be a net improvement in water quality from the construction of stormwater treatment wetlands that are not currently present on this section of the road.

Table 4.6 – The amount of impervious area in the catchment before and after the Project.

Site	catchment area ha	Impervious area current ha	Impervious area current %	Impervious area after Project ha	Impervious area after Project %
Mangapepeke Stream at SH3 road	330	2.03	0.61%	7.91	2.40%
Mangapepeke Stream at Ea10	149	1.61	1.08%	5.99	4.02%
Mimi River tributary at Ea26	221	2.44	1.10%	4.64	2.10%
Mimi River at E7	919	2.82	0.31%	6.20	0.67%

4.4 Mitigation and monitoring

4.4.1 Summary of mitigation

Previous sections have discussed a range of mitigation measures to address potential effects of the Project. The key mitigation and management plans measures are summarised below; they are:

- Develop and implement Fish Recovery Protocols for the recovery, rescue and relocation of native fish.
- Minimise the effect on upstream fish passage of temporary culverts that will be required for more than a few days, ie temporary culverts associated with large areas of fill near the tunnel (tributaries Ea16 and Ea19). This can be done by installing spat rope through the temporary culverts.
- Provide fish passage through permanent culverts and stream diversions that is appropriate for the fish present in the stream. This should include:
    - Use of arch culverts in large streams where practicable.
    - Where possible, and in low gradient streams, culverts should be installed with a low gradient (eg <0.3%) should have their downstream invert below the stream bed by about 20% of the culvert diameter.
    - On steeper grade culverts use baffles to retain substrate, slow velocities and provide turbulence. Flexible polymer iris baffles are likely to provide a robust option for most culverts.
    - Only rely on spat rope for fish passage in steep gradient culverts where other solutions are not practicable and where natural barriers (waterfalls) restrict the upstream fish community to climbing species.
    - Designing culvert outlets to provide a resting pool near the outlet and ensure at least 100mm of water depth is retained at culvert outlet and over the apron. This might be achieved using V-vanes (cross-vane) made from boulders.
- Install fish habitat devices within low gradient culverts on the larger streams (>25 ha) in order to mitigate their effect on fish habitat.
- Minimise disturbance of streams and riparian areas during construction. Where streams and riparian area are piped, diverted or disturbed by temporary works outside the Project footprint then the stream channel and riparian margin should be restored.

- Base the design of stream diversions on Ecological Design Principles. Preliminary and final stream designs should be prepared by experienced engineers, aquatic ecologist and landscape architects. This should include a description of stream width, morphology, form and riparian vegetation.
- Develop and implement a Stream Restoration Plan as part of the ELMP for stream diversions and stream affected short term by the works, including:
  - o Length of stream affected;
  - o Long section and typical cross-sections for stream diversions with a meandering form and in more steep, confined landscapes. These should be consistent with ecological design principles;
  - o Description of work to remove structures;
  - o Description of riparian planting and minimum widths planted;
  - o Timing of restoration work. Planting should occur as soon as practical after earthworks being completed to reduce risks of erosion and avoid unnecessary delays in restoration; and
  - o Monitoring of implementation.
- Effective implementation is key to achieving good restoration outcomes. An experienced ecologist should be available to give advice and guidance during construction of the new stream channel.
- Monitor the success of implanted stream diversions to ensure they are tracking towards achieving the ecological values assumed the SEV.
- Implement the Construction Water Management Plan to minimise and mitigate the effects of erosion and sedimentation. Particular attention should be given to reduction potential effects on sensitive areas such as the Mimi Valley Kahikatea swamp forest (see also Ridley and Parackal 2017).
- A Vegetation Clearance Protocol should be prepared, this should include procedures for minimising exposed soil and erosion from vegetation clearance operations, location of wood residue piles away from any waterways, collection and treatment of any leachate from wood residue piles.
- Undertake baseline monitoring and ongoing monitoring during the construction period of water quality and fish at selected sites to assess the effect of construction works. The baseline water quality monitoring should characterise natural variation in sediment concentration or deposition that occurs within the streams.

4.4.2 Biodiversity Offset

Biodiversity offsets can be used to achieve ‘no net loss’ or a ‘net positive gain’ where residual effects remain after applying a hierarchy of avoiding, minimising and mitigating the effects on ecology. They are measures to counterbalance any residual environmental effects.

Even with the mitigation set out above, the Project will result in a very high adverse environmental effect due to stream loss. The amount of stream restoration required to achieve sufficient biodiversity offset was calculated by using the SEV method. Based on current calculations the offset restoration must include:

- Restoration of 8,724m^2 of stream habitat; and
- Development of a Stream Restoration Plan as part of the ELMP to ensure use of appropriate species and sufficient overall improvement of stream values at the restoration sites.

The approach used for calculating ECRs means that where a stream diversion is returned to its current condition or worse (eg near sites E5 and E6), then these lengths should not be counted with any offset package (i.e. it is rehabilitation not offset). However, if a stream section is restored to be substantially better than its current condition, then this length can be included as part of the offset package.

Areas chosen for offset should ideally be 'on-site' and within the same catchment, but in practice this is often challenging. If the offset streams are off-site then they should be a similar size and order. The Mangapepeke Stream and Mimi River upstream of the current SH3 have high potential for successfully improving stream values through riparian planting and restoration, subject to obtaining the necessary access rights. This is because the restoration can be contiguous with the forested headwaters, which helps ensure good water quality, a source of plant seed and wood, and more rapid colonisation by invertebrates and fish.

Restoration planting along streams is typically done along a strip of land to provide, for example, a 10m riparian margin. However, the Mt Messenger offset package will include other restoration planting and long-term pest control to act as biodiversity offset for effects on terrestrial flora and fauna. Applying the different offset compensation measures in the same location will provide synergistic benefits for streams. For example, planting additional stream width provides additional improvement in ecosystem functions, pest control operations can reduce streambank erosion and trampling of spawning sites. These synergistic benefits are hard to quantify but could work to provide a net positive outcome for the Mangapepeke Stream and Mimi River.

The amount of offset required is based on the designs available in the AEE drawing set. The amount of offset to achieve 'no net loss' of stream habitat should be recalculated if there are substantive changes to designs that affect streams.

4.4.3 Further investigations

While sufficient data have been gathered to support this assessment, the following additional investigations are recommended to improve understanding of the potential adverse effects of the Project, and potential further mitigation measures:

- Additional fish surveys should be undertaken in the intermittent tributaries where the proposed culvert will have steep gradient or scruffy domes will be installed (ie Sites Ea2, Ea11, Ea12, Ea13, Ea14, Ea15 and Ea21). Surveys should occur spring / early summer. These will provide more confidence about whether fish and koura are present or absent from these sites and the proposed designs for fish passage.
- Undertake a morphological survey downstream of the proposed water takes on Mimi River and Mangapepeke Stream during base flow conditions. This will provide

information about the potential effects of the water takes if more than the proposed 10% of the flow is taken from each stream.

- The SEV calculations assumed that stream restoration for offset purposes would occur in the upper Mimi River and Mangapepeke Stream. These locations may not be available. If other sites are used for stream offset then there may need to be additional SEV surveys of the restoration sites and recalculate offset requirements.
- Consideration should be given to initiating early baseline monitoring of settleable sediment, particularly in the tributary to the Mimi River. This will better characterise the current sediment load upstream of the Kahikatea swamp forest. .

5 Conclusions

The Project will affect 2,447m of stream in the Mangapepeke Stream catchment and 1,023m of stream in the Mimi River catchment. The impacted streams have moderate to high ecological values, and a diverse fish community.

The potential effects on streams during the construction period can be reduced and mitigated by implementing good practice with respect to erosion and sediment control, fish recovery, vegetation clearance, water takes and undertaking monitoring during the construction period. Similarly, many of the long-term effects from the road footprint can be minimised and mitigated by good culvert design to ensure fish passage, stormwater management, and design of stream diversions. Nevertheless, the piping and diversion of streams required by the Project will cause considerable loss of streams that, in the absence of a biodiversity offset, would constitute a very high adverse effect.

The SEV method calculated that to address the effects of stream loss will require restoration of 8,724m^2 of stream habitat. Streams in the Mangapepeke Stream and Mimi River have good potential for successful restoration that could be used as a biodiversity offset to balance the effect from piping and diversions.

Overall, the effects of the Project on freshwater ecology can be appropriately managed and mitigated, and the residual loss of habitat can be adequately offset to result in 'no net loss' of stream values.

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Appendices

Appendix A: National rapid habitat assessment protocol

Habitat parameter	Condition category										SCORE
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	10	9	8	7	6	5	4	3	2	1	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	10	9	8	7	6	5	4	3	2	1	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	10	9	8	7	6	5	4	3	2	1	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	10	9	8	7	6	5	4	3	2	1	
5. Fish cover abundance	*The percentage of fish cover available.*										
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	10	9	8	7	6	5	4	3	2	1	
6. Hydraulic heterogeneity	*The number of of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulance, backwater. Presence of deep pools score higher.*										
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	10	9	8	7	6	5	4	3	2	1	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	10	9	8	7	6	5	4	3	2	1	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										
Left bank AND Right bank	*Mature native trees with diverse and intact understorey*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	10	9	8	7	6	5	4	3	2	1	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	10	9	8	7	6	5	4	3	2	1	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	10	9	8	7	6	5	4	3	2	1	
TOTAL	(Sum of parameters 1-10)										

Appendix B: Macroinvertebrate results

Table B1: Mt Messenger sites, 7-8 June 2017

TAXON	MCI score	E2	E3	E4	E5	E6 Mimi	E7 Mimi
ACARINA	5					4	
COLEOPTERA							
Elmidae	6		20	213	18	36	10
Hydraenidae	8				2	16	
Ptilodactylidae	8					4	
Scirtidae	8			7		4	
CRUSTACEA							
Isopoda	5					12	
Paracalliope fluviatilis	5	1040					370
Paraleptamphopus species	5					52	
Paranephrops planifrons	5		1				
Paratya species	5	1					
Talitridae	5					4	
DIPTERA							
Aphrophila species	5			7			
Austrosimulium species	3	200	720	33	2		120
Ceratopogonidae	3					4	
Empididae	3					16	
Eriopterini	9			20			
Hexatomini	5		1	7			
Orthocladiinae	2	20	100	7	2		1
Tanypodinae	5		1			1	1
Tanytarsini	3		40		1		
EPHEMEROPTERA							
Acanthophlebia species	7					1	
Ameletopsis perscitus	10					1	
Austroclima species	9	460	800	7			330
Coloburiscus humeralis	9			20	12	28	
Deleatidium species	8	10	40	580	96	148	220
Ichthybotus species	8					4	
Mauiulus luma	5		140				10
Neozephlebia scita	7	110	480		2	20	70
Nesameletus species	9		20			8	50
Zephlebia species	7	30	140	40	18	172	530
HEMIPTERA							
Sigara species	5	10					
HIRUDINEA	3		40				
MEGALOPTERA							
Archichauliodes diversus	7			7	6	1	1
MOLLUSCA							
Lymnaeidae	3	1	20				
Potamopyrgus antipodarum	4	420	9400	247	132	192	830
Sphaeriidae	3		20				
NEMATODA	3	20	1				
NEMERTEA	3	10	1				
ODONATA							
Antipodochlora species	6		1				
Xanthocnemis zealandica	5	1	1				
OLIGOCHAETA	1	30	120	1		40	1
PLATYHELMINTHES	3	1					
PLECOPTERA							
Acroperla species	5	40		153	98	64	30
Austroperla cyrene	9				4	8	
Megaleptoperla species	9		20				20
Spaniocerca species	8			7			
Zelandobius species	5		1	7		28	
Zelandoperla species	10					4	
TRICHOPTERA							
Helicopsyche species	10			60	36		
Hudsonema alienum	6	1	20				30
Hudsonema amabile	6	20	1				1
Hydrobiosella species	9					20	
Hydrobiosis clavigera group	5			1			1
Hydrobiosis umbripennis group	5	1	1	1			1
Oecetis species	6		1				1
Orthopsyche species	9			1	4	96	
Polyplectropus species	8		1			1	10
Psilochorema species	8	1					1
Pycnocentria species	7	10	1		2		10
Pycnocentrodes species	5						1
Triplectides species	5	10	80	7			10
Zelandoptila species	8						10

Table B2: Mt Messenger sites, 31 July to 1 August 2017

TAXON	MCI score	Ea10	Ea13	Ea26 Mimi	Ea27 Mimi	Ea28 Mimi drain
ACARINA	5		1	3		7
COLEOPTERA						
Dytiscidae	5					1
Elmidae	6	180	1			
Staphylinidae	5		1			
COLLEMBOLA	6	17	2	3		
CRUSTACEA						
Cladocera	5					7
Isopoda	5			1		
Ostracoda	3					680
Paracalliope fluviatilis	5			35	20	7
DIPTERA						
Austrosimulium species	3	40		58	110	107
Ceratopogonidae	3					20
Chironomus species	1					53
Eriopterini	9	1	1	3		
Hexatomini	5		1			
Mischoderus species	4	3				
Molophilus species	5			1		
Orthocladiinae	2	3	4	8		347
Paradixa species	4		1	1		7
Paralimnophila skusei	6					27
Polypedilum species	3	3		3		7
Tanypodinae	5					40
Tanytarsini	3	3	2			7
EPHEMEROPTERA						
Acanthophlebia species	7		1			
Austroclima species	9	23		428	525	
Coloburiscus humeralis	9	10	2	3		
Deleatidium species	8	280	114	20	25	7
Neozephlebia scita	7	3	3	53	30	
Nesameletus species	9	7		33	30	
Zephlebia species	7	40	40	125	140	
HEMIPTERA						
Microvelia macgregori	5					1
Sigara species	5					1
HIRUDINEA	3					20
MEGALOPTERA						
Archichauliodes diversus	7	3		3		
MOLLUSCA						
Lymnaeidae	3					1
Potamopyrgus antipodarum	4	67	3	293	270	100
NEMERTEA	3					20
ODONATA						
Austrolestes colensonis	6					1
Xanthocnemis zealandica	5					107
OLIGOCHAETA	1		3	5		207
PLATYHELMINTHES	3					120
PLECOPTERA						
Acroperla species	5	33	6	28	15	
Megaleptoperla species	9			8	5	
Spaniocercoides species	8		2			
Zelandobius species	5	7	16	5	10	13
TRICHOPTERA						
Helicopsyche species	10	10				
Hudsonema alienum	6			1	25	
Hydrobiosella species	9		6			
Hydrobiosidae early instar	5		1			
Hydrobiosis umbripennis group	5	13		5	1	
Orthopsyche species	9	3	3			
Oxyethira albiceps	2					47
Psilochorema species	8			1		20
Pycnocentria species	7	23	2	35	20	
Pycnocentrodes species	5	7				
Triplectides species	5			5	10	
Zelandoptila species	8			8		

Appendix C: SEV calculations

Table C 1 – Results of SEV calculations sites along the route, Mt Messenger

ca. 8 June and 31 July 2017		Test sites Site name/number										Reference sites Site name/number		
Function category	**Variable**	**E2**	**E3**	**E4**	**E5**	**Ea28**	**E7**	**Ea10**	**Ea13**	**Ea26**	**Ea27**	**E6**	**Wai Pingao**	**N7**
	Vchann	0.80	1.00	0.92	0.95	0.10	0.80	1.00	1.00	0.50	0.80	1.00	1.00	1.00
	Vlining	0.86	0.96	0.98	1.00	0.80	0.80	0.96	1.00	1.00	0.80	1.00	1.00	1.00
	Vpipe	1.00	1.00	1.00	1.00	1.00	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hydraulic	=	**0.82**	**0.99**	**0.94**	**0.97**	**0.33**	**0.56**	**0.99**	**1.00**	**0.67**	**0.80**	**1.00**	**1.00**	**1.00**
	Vbank	1.00	1.00	1.00	1.00	1.00	0.92	1.00	1.00	0.92	0.92	1.00	1.00	1.00
	Vrough	0.20	0.20	0.64	1.00	0.16	0.21	0.44	0.92	0.44	0.20	1.00	1.00	1.00
Hydraulic	=	**0.20**	**0.20**	**0.64**	**1.00**	**0.16**	**0.19**	**0.44**	**0.92**	**0.40**	**0.18**	**1.00**	**1.00**	**1.00**
	Vbarr	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.30
Hydraulic	=	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0.30**
	Vchanshape	0.40	1.00	0.76	0.96	0.20	0.40	1.00	1.00	0.60	0.40	1.00	1.00	1.00
	Vlining	0.86	0.96	0.98	1.00	0.80	0.80	0.96	1.00	1.00	0.80	1.00	1.00	1.00
Hydraulic	=	**0.71**	**0.97**	**0.91**	**0.99**	**0.60**	**0.67**	**0.97**	**1.00**	**0.87**	**0.67**	**1.00**	**1.00**	**1.00**
Hydraulic function mean score		**0.68**	**0.79**	**0.87**	**0.99**	**0.52**	**0.60**	**0.85**	**0.98**	**0.73**	**0.66**	**1.00**	**1.00**	**0.83**
	Vshade	0.26	0.24	0.44	0.72	0.00	0.18	0.52	0.88	0.26	0.14	0.90	0.94	0.92
biogeochemical	=	**0.26**	**0.24**	**0.44**	**0.72**	**0.00**	**0.18**	**0.52**	**0.88**	**0.26**	**0.14**	**0.90**	**0.94**	**0.92**
	Vdod	0.68	0.60	1.00	1.00	0.68	0.68	1.00	1.00	1.00	0.68	1.00	1.00	1.00
biogeochemical	=	**0.68**	**0.60**	**1.00**	**1.00**	**0.68**	**0.68**	**1.00**	**1.00**	**1.00**	**0.68**	**1.00**	**1.00**	**1.00**
	Vripar	0.05	0.15	0.60	0.95	0.00	0.04	0.50	0.80	0.20	0.05	1.00	1.00	1.00
	Vdecid	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
biogeochemical	=	**0.05**	**0.15**	**0.60**	**0.95**	**0.00**	**0.04**	**0.50**	**0.80**	**0.20**	**0.05**	**1.00**	**1.00**	**1.00**
	Vmacro	0.75	0.81	0.96	1.00	0.79	0.90	0.99	1.00	0.91	0.93	1.00	1.00	1.00
	Vretain	0.60	1.00	0.84	0.98	0.20	0.60	1.00	1.00	0.80	0.60	1.00	1.00	1.00
biogeochemical	=	**0.60**	**0.81**	**0.84**	**0.98**	**0.20**	**0.60**	**0.99**	**1.00**	**0.80**	**0.60**	**1.00**	**1.00**	**1.00**
	Vsurf	0.79	0.82	0.42	0.41	0.65	0.59	0.53	0.39	0.52	0.69	0.57	0.36	0.38
	Vripfilt	0.80	0.80	0.52	1.00	0.36	0.57	0.30	0.92	0.64	0.56	1.00	1.00	1.00
biogeochemical	=	**0.80**	**0.81**	**0.47**	**0.71**	**0.50**	**0.58**	**0.41**	**0.66**	**0.58**	**0.63**	**0.79**	**0.68**	**0.69**
Biogeochemical function mean score		**0.48**	**0.52**	**0.67**	**0.87**	**0.28**	**0.41**	**0.69**	**0.87**	**0.57**	**0.42**	**0.94**	**0.92**	**0.92**
	Vgalspwn	1.00	1.00	1.00	0.85	1.00	0.83	0.70	1.00	0.55	1.00	1.00	0.85	1.00
	Vgalqual	0.75	0.25	0.00	1.00	0.00	0.00	0.00	0.75	0.00	0.00	1.00	1.00	1.00
	Vgobspwn	0.20	0.20	0.80	1.00	0.10	0.80	0.80	0.10	0.20	1.00	0.80	0.80	0.80
habitat provision	=	**0.48**	**0.23**	**0.40**	**0.93**	**0.05**	**0.40**	**0.40**	**0.43**	**0.10**	**0.50**	**0.90**	**0.83**	**0.90**
	Vphyshab	0.53	0.56	0.64	0.99	0.19	0.58	0.87	0.88	0.66	0.52	1.00	1.00	1.00
	Vwatqual	0.43	0.37	0.72	0.86	0.17	0.40	0.76	0.94	0.63	0.38	0.95	0.97	0.96
	Vimperv	1.00	1.00	1.00	1.00	1.00	0.90	1.00	1.00	1.00	1.00	1.00	0.90	0.90
habitat provision	=	**0.62**	**0.63**	**0.75**	**0.96**	**0.39**	**0.61**	**0.88**	**0.93**	**0.74**	**0.61**	**0.99**	**0.97**	**0.97**
Habitat provision function mean score		**0.55**	**0.43**	**0.57**	**0.94**	**0.22**	**0.51**	**0.64**	**0.68**	**0.42**	**0.55**	**0.94**	**0.90**	**0.93**
	Vfish	0.87	0.60	0.60	0.90	0.37	0.90	0.90	0.70	0.90	0.90	0.77	0.97	0.70
Biodiversity	=	**0.87**	**0.60**	**0.60**	**0.90**	**0.37**	**0.90**	**0.90**	**0.70**	**0.90**	**0.90**	**0.77**	**0.97**	**0.70**
	Vmci	0.56	0.74	0.96	1.00	0.41	0.90	0.97	1.00	0.95	0.94	1.00	0.90	1.00
	Vept	1.00	1.00	1.00	0.50	0.67	1.00	1.00	1.00	1.00	1.00	0.83	0.67	1.00
	Vinvert	0.47	0.70	0.35	0.66	0.47	0.58	0.35	0.35	0.58	0.35	0.77	0.82	0.47
Biodiversity	=	**0.67**	**0.81**	**0.77**	**0.72**	**0.51**	**0.83**	**0.77**	**0.78**	**0.85**	**0.76**	**0.87**	**0.80**	**0.82**
	Vripcond	0.20	0.20	0.69	1.00	0.08	0.12	0.50	0.94	0.28	0.10	1.00	1.00	0.98
	Vripconn	0.90	1.00	1.00	1.00	1.00	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Biodiversity	=	**0.18**	**0.20**	**0.69**	**1.00**	**0.08**	**0.10**	**0.50**	**0.94**	**0.28**	**0.10**	**1.00**	**1.00**	**0.98**
Biodiversity function mean score		**0.57**	**0.54**	**0.69**	**0.87**	**0.32**	**0.61**	**0.72**	**0.81**	**0.68**	**0.59**	**0.88**	**0.92**	**0.83**
Overall mean SEV score (maximum value 1)		**0.57**	**0.59**	**0.72**	**0.92**	**0.35**	**0.52**	**0.73**	**0.86**	**0.62**	**0.54**	**0.94**	**0.94**	**0.88**

Table C 2 – Calculations for the amount of stream biodiversity offset required to address the impact on streams from the road footprint.

Site	Catchment	catchment area (ha)	ID culvert / diverson	width (m)	depth run	depth pool (m)	survey method	Permanent, short term,	SEVi-C	SEVi-P	SEVi-I	SEVm-P - SEVm-C	ECR	Length of impact (m)	Area of impact (m^2)	Length to restore (m)	Area to restore (m^2)
Ea1	Mangapepeke trib	3.82	1	0.3	0.03	0.05		P	0.75	0.75	0.23	0.24	3.3	15	4.5	49	15
Ea2	Mangapepeke trib	1.80	2	0.2				P	0.5	0.65	0.23	0.24	2.6	15	3	39	8
E1	Mangapepeke	328		1.4	0.4	0.8	H, F						n.a.	0	0		
Ea3	Mangapepeke trib	6.3	3	*0.5*				P	0.4	0.77	0.23	0.24	3.4	65	32.5	219	110
Ea4	Mangapepeke trib	1.8	4	*0.2*				P	0.57	0.77	0.4	0.24	2.3	35	7	81	16
Ea5	Mangapepeke trib	4.2	5	*0.5*				P	0.57	0.77	0.23	0.24	3.4	44	22	149	74
E2	Mangapepeke	306		1.4	0.4	0.8	SEV, H		**0.57**	**0.77**			n.a.	0	0		
Ea6	Mangapepeke trib	4.4	swale	*0.5*				P	0.58	0.77	0.4	0.24	2.3	38	19	88	44
Ea7	Mangapepeke trib	6.8	6	*0.5*				P	0.57	0.77	0.23	0.24	3.4	38	19	128	64
E2a	Mangapepeke	248		1.3	0.4	0.5	H		0.58	0.77			n.a.	0	0		
Ea8	Mangapepeke trib	5.8	7	*0.5*				P	0.57	0.77	0.23	0.24	3.4	40	20	135	68
Ea9	Mangapepeke trib	7.9	8	*0.65*				P	0.57	0.77	0.23	0.24	3.4	37	24.05	125	81
Ea10a	Mangapepeke trib	67	9	1	0.3	1.5	SEV, H,	P	**0.73**	**0.86**	0.23	0.24	**7.9**	70	70	551	551
Ea10b	Mangapepeke	149	SD5	1.2	0.4	1.5		D	**0.73**	**0.86**	0.75	0.24	**2.0**	100	120	200	240
E3	Mangapepeke	133		1.25	0.35	0.45	SEV, H		**0.58**	**0.77**			n.a.	0	0		
Ea11	Mangapepeke trib	2	10	0.2	0.01			P	0.86	0.86	0.23	0.24	3.9	35	7	138	28
Ea12	Mangapepeke trib	1.6	11	0.2	0.01			P	0.86	0.86	0.23	0.24	3.9	34	6.8	134	27
Ea13	Mangapepeke trib	9.8	12	0.75	0.1	0.3	SEV, H	P	**0.86**	**0.86**	0.23	0.24	3.9	85	63.75	335	251
E4	Mangapepeke	116		1.8	0.25	0.4	SEV, H, F		**0.72**	**0.86**			n.a.	0	0		
Ea14	Mangapepeke trib	1.7	13	0.3	0.01	0.2		P	0.86	0.86	0.23	0.24	3.9	32	9.6	126	38
E5	Mangapepeke	64	SD6	2.5	0.25	1.5	SEV, H, F	D	**0.92**	**0.92**	0.55	0.24	2.3	80	200	185	463
E5b	Mangapepeke			2.5				P	**0.92**	**0.92**	0.23	0.24	4.3	180	450	776	1941
Ea15	Mangapepeke trib	5	14	0.6	0.1			P	0.86	0.86	0.23	0.24	3.9	95	57	374	224
Ea16	Mangapepeke trib	36	15	1.2	0.35			P	0.92	0.92	0.23	0.24	4.3	77	92.4	332	398
Ea17	Mangapepeke trib	17	SD7	1	0.15	0.5		D	0.92	0.92	0.55	0.24	2.3	400	400	925	925
Ea18	Mimi trib	6	SD8	0.5	0.08			D	0.94	0.94	0.55	0.24	2.4	250	125	609	305
Ea19	Mimi trib	10	16	0.9				P	0.94	0.94	0.23	0.24	4.4	40	36	178	160
E6	Mimi trib	21		1.2	0.15	0.55	SEV, H, F	P	**0.94**	**0.94**	0.23	0.24	4.4	165	198	732	879
Ea20	Mimi trib	15	Bridge	0.9	0.1	0.5			0.86	0.86			n.a.	0	0		
Ea21	Mimi trib	3	17	0.5	0.02	0.35	H	P	0.86	0.86	0.23	0.24	3.9	33	16.5	130	65
Ea22	Mimi trib	1.5	swale	0.4	0.05		H	P	0.35	0.77	0.4	0.24	2.3	50	20	116	46
Ea23	Mimi trib	25	18/19	0.9				P	0.73	0.8	0.23	0.24	3.6	55	49.5	196	176
E7	Mimi	919		2.1	0.46	0.8	SEV, H, F	D	**0.52**		**0.52**		**0.5**	40	84	20	42
Ea24	Mimi trib	13	20	0.6	0.1			P	0.35	0.77	0.23	0.24	3.4	10	6	34	20
Ea29	Mimi trib	12	21	0.6				P	0.35	0.77	0.23	0.24	3.4	10	6	34	20

Table C 3 – Calculations for the amount of stream biodiversity offset required to address the impact on streams of tracks, fill and ponds associated with the road.

Site	catchment area (ha)	width (m)	comment	Permanent, short term, diversion	SEVi-C	SEVi-P	SEVi-I	SEVm-P - SEVm-C	ECR	Length of impact (m)	Area of impact (m^2)	Area to restore (m^2)
E TL1	1.3	0.2	extend culvert on farm track	P	0.55	0.77	0.23	0.24	3.4	5	1	3
E TL2	1.9	0.2	extend culvert on farm track	P	0.55	0.86	0.23	0.24	3.9	5	1	4
E TL3	2.1	0.3	Fill - diversion section	D	0.55		0.55		0.5	75	22.5	11
E TL3		0.3	Fill - culvert section	P	0.55	0.77	0.23	0.24	3.4	5	1.5	5
E TL4	6.6	0.5	Fill - diversion section	D	0.55		0.55		0.5	175	87.5	44
E TL4		0.5	Fill - culvert section	P	0.55	0.77	0.23	0.24	3.4	5	2.5	8
E TL5	32	0.8	Riffle-pool form, width 0.5-1.0m. Bank height 0.5m	P	0.55	0.86	0.23	0.24	3.9	5	4	16
E TL6	3.1	0.4	extend culvert on farm track	P	0.55	0.86	0.23	0.24	3.9	5	2	8
Ea3	6.3	0.5	Fill culvert under	P	0.57	0.77	0.223	0.24	3.4	35	17.5	60
Ea3	6.3	*0.5*	access track	S	0.57		0.5		0.5	10	5	3
Ea4	1.8	*0.2*	Fill culvert under	P	0.57	0.77	0.23	0.24	3.4	40	8	27
Ea5	4.2	*0.4*	Fill culvert under	P	0.57	0.77	0.23	0.24	3.4	60	24	81
Ea7	6.8	0.5	sediment retention ponds etc	S	0.57		0.57		0.5	40	20	10
Ea8	5.8	*0.5*	works area, dirty water drain	S	0.57		0.57		0.5	37	18.5	9
Ea9	7.9	*0.65*	works area, dirty water drain	S	0.57		0.57		0.5	15	9.75	5
E2		1.4	Accrss track crossing x3	S	**0.57**		0.58		0.5	45	63	32
Ea10b	149	1.2	works area, dirty water drain, access track crossing	S	**0.73**	**0.86**	0.75	0.24	**2.0**	35	42	84
E3		1.25	Access track crossing + dirty water	S	**0.58**		0.58		0.5	15	18.75	9
Ea11	2	0.2	access track	S	0.86	0.86	0.75	0.24	0.7	15	3	2
Ea12	1.6	0.2	dirty water drain	S	0.86	0.86	0.75	0.24	0.7	20	4	3
Ea13	9.8	0.75	clean water diversion works	S	**0.86**	**0.86**	0.75	0.24	0.7	20	15	10
E4	116	1.8	inside temporary footprint	S	**0.72**	**0.85**	0.75	0.24	0.6	50	90	56
Ea14	1.7	0.3	access track + dirtywater drain	S	0.86	0.86	0.75	0.24	0.7	15	4.5	3
E5		2.5	access track + dirtywater drain	S	**0.92**	**0.92**	0.75	0.24	1.1	100	250	266
Ea15	5	0.6	temporary works upstream	S	0.86	0.86	0.75	0.24	0.7	50	30	21
Ea16	36	1.2	temporary works upstream	S	0.92	0.92	0.75	0.24	1.1	50	60	64
E6	21	1.2	ponds,	S	**0.94**	**0.94**	0.75	0.24	1.2	50	60	71
Ea23	25	0.9	fill upstream of SH3	P	0.73	0.8	0.23	0.24	3.6	160	144	513
Ea30	2.9	0.4	farm cutoff drain affected by fill	D	0.4		0.4		0.5	160	64	32

Appendix D: Site Photos

Figure D 1 – Site Ea1, intermittent tributary to Mangapepeke Stream.

Figure D 2 – Site E1 Mangapepeke Stream

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Figure D 3 – Site Ea3, tributary to Mangapepeke Stream entering at site E1. Recent drain clearance.

Figure D 4 – Site E2 Mangapepeke Stream.

Figure D 5 – Site E2a Mangapepeke Stream.

Figure D 6 - Site ETL5 Tributary to Mangapepeke Stream being crossed by access the access track, June 2017.

Figure D 7 - Site Ea10 Mangapepeke Stream tributary.

Figure D 8 – Mangapepeke Stream upstream of site Ea10 tributary, August 2017. Degraded kahikatea swamp forest.

Figure D 9 – Mangapepeke Stream upstream of site Ea10, facing upstream, August 2017.

Figure D 10 – Site E3 Mangapepeke Stream, facing downstream.

Figure D 11 – Site Ea12, intermittent tributary to Mangapepeke Stream.

Figure D 12 – Site Ea13, tributary to Mangapepeke Stream.

Figure D 13 – Site E4 Mangapepeke Stream. Sediment deposition on stream bank from a recent flood, 7 June 2017.

Figure D 14 – Site Ea14 tributary to Mangapepeke Stream and waterfall.

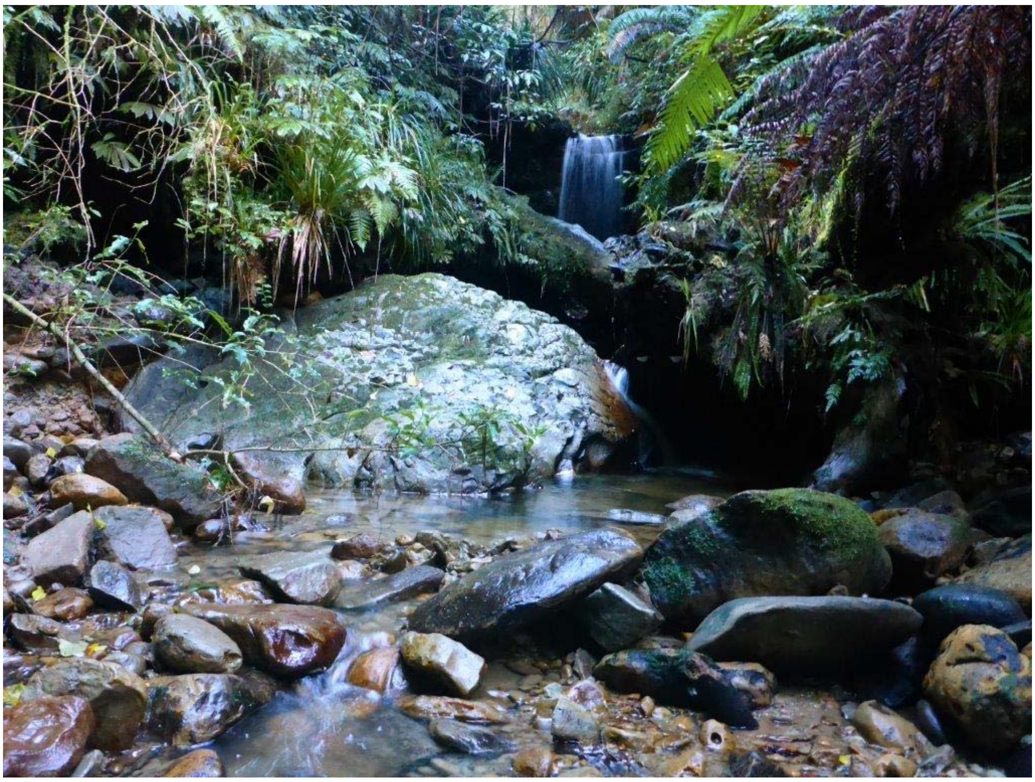

Figure D 15 – Site E5 Mangapepeke Stream.

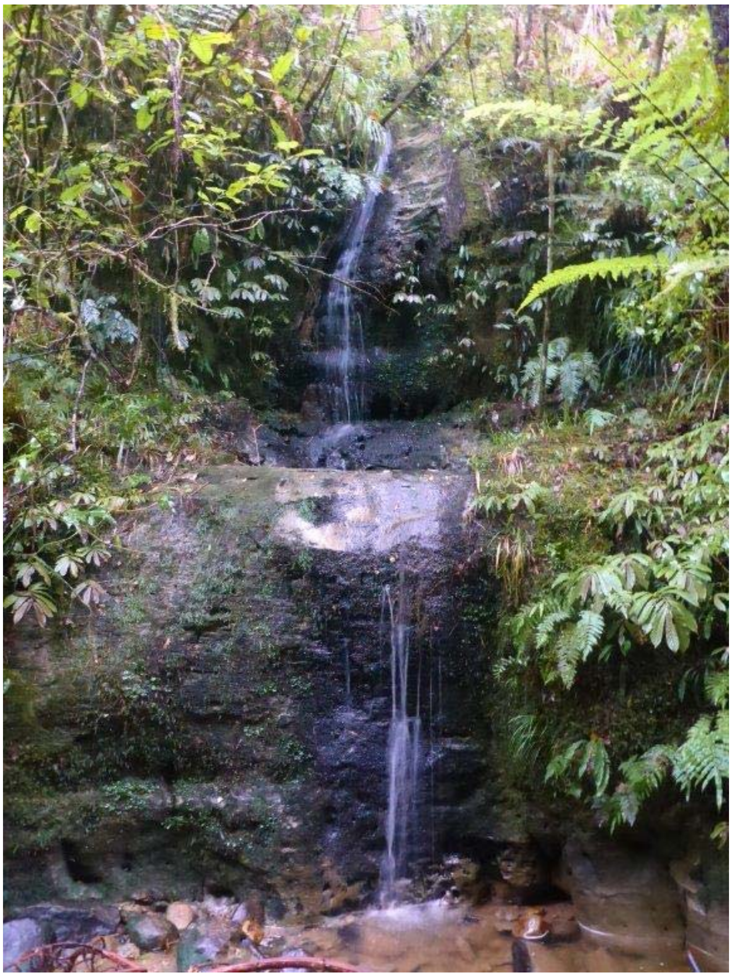

Figure D 16 – Site Ea15, tributary to Mangapepeke Stream entering at site E5, August 2017.

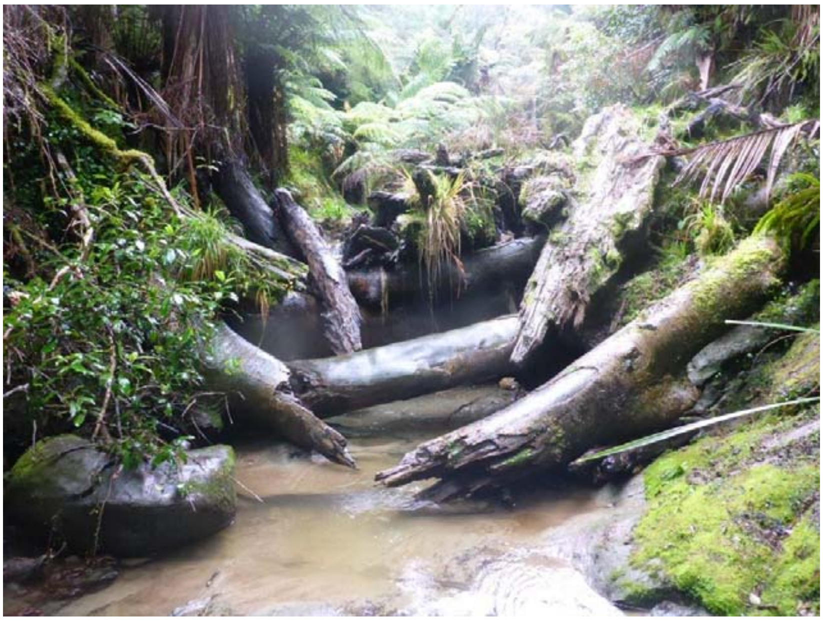

Figure D 17 – Log jam in Mangapepeke Stream upstream of site E5 waterfall.

Figure D 18 - Mangapepeke Stream upstream of site E5 waterfall.

Figure D 19 - Site Ea16 Mangapepeke Stream, August 2017.

Figure D 20 – Site Ea17 Mangapepeke Stream, August 2017

Figure D 21 – Site Ea19, Mimi River tributary, August 2017.

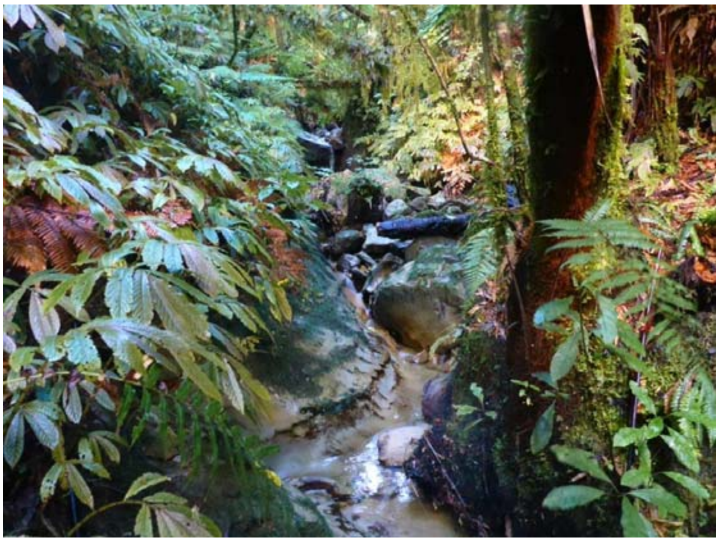

Figure D 22 – Site E6 Mimi River tributary (upper end of reach).

Figure D 23 – Site E6 Mimi River tributary (lower end of reach).

Figure D 24 – Site Ea25 Mimi River tributary. Kahikatea swamp forest downstream of site E6

Figure D 25 – Site Ea20, Mimi River tributary. Kahikatea forest section being bridged.

Figure D 26 – Site Ea21, Mimi River tributary.

Figure D 27 – Site Ea22 Mimi River.

Figure D 28 – Site Ea26 Mimi River tributary, facing downstream.

Figure D 29 – Site Ea27, Mimi River facing upstream, August 2017.

Figure D 30 – Site E7 Mimi River facing downstream, June 2017.

Figure D 31 – Site Ea28, Mimi River tributary facing downstream. Water turbid due to runoff from cattle pugging.

Figure D 32 – Mangapepeke Stream culvert under the current SH3 north of Mt Messenger, August 2017. This site is not affected by the Project.