Warkworth to Wellsford

Operational Water - Design

Technical Report

July 2019

Prepared by

Jacobs GHD Joint Venture in association with Tonkin & Taylor Ltd. Prepared subject to the terms of the Professional Services Contract between the Client and Jacobs GHD Joint Venture for the Route Protection and Consenting of the Warkworth to Wellsford Project.

QUALITY ASSURANCE

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GLOSSARY AND DEFINED TERMS

Refer to the Water Assessment Report for a master glossary and defined terms table.

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1 INTRODUCTION

The Warkworth to Wellsford Project (the Project) crosses the Mahurangi River, Hōteo River and tributaries of the Oruawharo River to the north of Auckland. These freshwater environments drain into the Mahurangi Harbour and Kaipara Harbour. This report has been prepared to support the Water Assessment Report for the Project, and provides details of the operational stormwater management and other operational phase mitigation by design.

1.1 Project description

The Project involves the construction, operation and maintenance of a new four lane state highway. The route is approximately 26 km long. The Project commences at the interface with the Pūhoi to Warkworth project (P-Wk) near Woodcocks Road. It passes to the west of the existing State Highway 1 (SH1) alignment near The Dome, before crossing SH1 just south of the Hōteo River. North of the Hōteo River the Project passes to the east of Wellsford and Te Hana, bypassing these centres. The Project ties into the existing SH1 to the north of Te Hana near Maeneene Road.

1.2 Project features

The key features of the Project, based on the Indicative Alignment, are as follows:

a) A new four lane dual carriageway state highway, offline from the existing State Highway 1, with the potential for crawler lanes on the steeper grades.

b) Three interchanges as follows:

   i. Warkworth Interchange, to tie-in with the Pūhoi to Warkworth section of state highway and provide a connection to the northern outskirts of Warkworth.

   ii. Wellsford Interchange, located at Wayby Valley Road to provide access to Wellsford and eastern communities including Tomarata and Mangawhai.

   iii. Te Hana Interchange, located at Mangawhai Road to provide access to Te Hana, Wellsford and communities including Port Albert, Tomarata and Mangawhai.

c) Twin bore tunnels under Kraack Road, each serving one direction, which are approximately 850 metres long and approximately 180 metres below ground level at the deepest point.

d) A series of steep cut and fills through the forestry area to the west of the existing SH1 within the Dome Valley and other areas of cut and fill along the remainder of the Project.

e) A viaduct (or twin bridge structures) approximately 485 metres long, to span over the existing SH1 and the Hōteo River.

f) A tie in to existing SH1 in the vicinity of Maeneene Road, including a bridge over Maeneene Stream.

g) Changes to local roads:

   i. Maintaining local road connections through grade separation (where one road is over or under the other). The Indicative Alignment passes over Woodcocks Road, Wayby Valley Road, Whangaripo Valley Road, Mangawhai

Road and Maeneene Road. The Indicative Alignment passes under Kaipara Flats Road, Rustybrook Road, Farmers Lime Road and Silver Hill Road.

ii. Realignment of sections of Wyllie Road, Carran Road, Kaipara Flats Road, Phillips Road, Wayby Valley Road, Mangawhai Road, Vipond Road, Maeneene Road and Waimanu Road.

iii. Closing sections of Phillips Road, Robertson Road, Vipond Road and unformed roads affected by the Project.

h) Associated works including bridges, culverts, drainage, stormwater treatment systems, soil disposal sites, signage, lighting at interchanges, landscaping, realignment of access points to local roads, and maintenance facilities.

i) Construction activities, including construction yards, lay down areas for storage of materials and establishment of construction access and haul roads.

A full description of the Project including its current design, construction and operation is provided in Section 4: Description of the Project and Section 5: Construction and Operation of the AEE contained in Volume 1 and shown on the Drawings in Volume 3.

1.3 Purpose and scope of this report

This Operational Water Design Report (this Report) forms part of a suite of water related design and technical reports prepared for the Ara Tūhono – Pūhoi to Wellsford – Warkworth to Wellsford section (the Project).

These reports are listed below with a short description of each:

- **Water Assessment Report (WAR) –** This report contains a summary of the work carried out and assessment of water rekated effects associated with consutruction and operation of the Project.
- **Construction Water Management Design technical report** – This report contains indicative details of the proposed construction methodology, proposed erosion and sediment controls (ESCs), and other construction phase mitigation measures recommended to reduce and erosion and sediment laden stormwater discharges from entering the receiving environment during construction.
- **Operational Water Design technical report (this report)** – This report contains details of the operational stormwater management and other operational phase mitigation by design.
- **Existing Water Quality technical report** – This report summarises water quality monitoring carried out by Auckland Council and for the Project.
- **Catchment Sediment Modelling technical report** – Sediment models have been developed to predict changes in sediment and water quality within receiving watercourses associated with the Project. This report summarises the modelling methodology and results.
- **Operational Water – Road Runoff technical report** – An assessment has been carried out to predict changes to water quality in relation to the Project and pollutants.

- **Flood Modelling technical report** – A model has been developed to predict any changes to flood risk associated with the Project. This report summarises any changes.

- **Hydrological technical report** – Catchment analysis has been developed to predict catchment wide hydrological changes associated with the Project. This report summarises predicted changes to the hydrological environment.

This purpose of this Operational Water Design Report is to document the various aspects of the operational stormwater design, (including the design of stormwater treatment devices, culverts and any associated stream diversions associated with the Indicative Alignment), in order to inform the Water Assessment Report, the Assessment of Effects on the Environment (AEE) and the resource consent applications and Notices of Requirement for the Project. The relationship between the reports is illustrated in Figure 1.

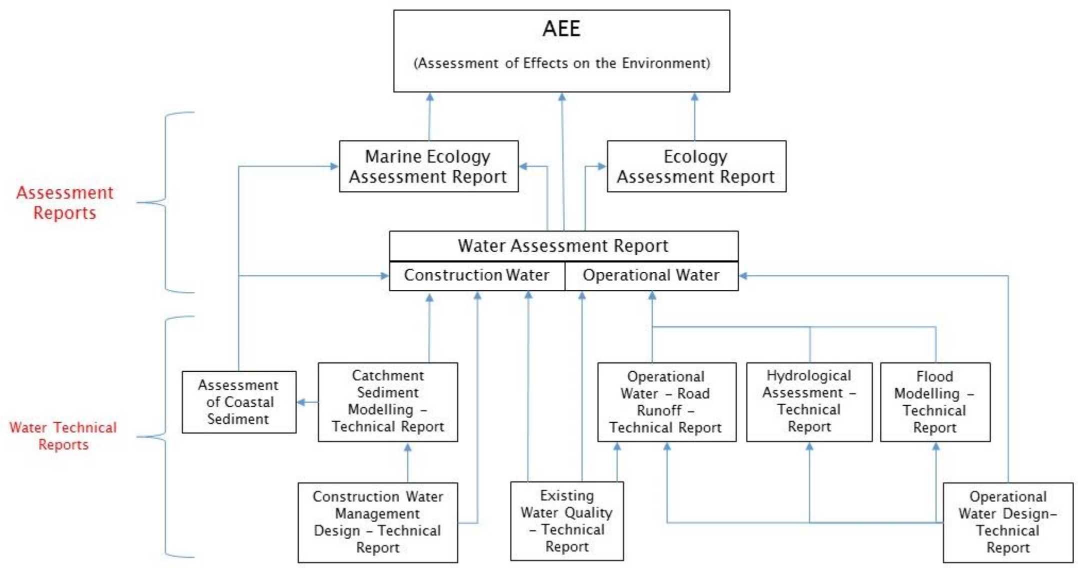

Figure 1 – Operational Water Design Report – Relationship to other reports

The Indicative Alignment shown on the Project drawings has developed through a series of multi-disciplinary specialist studies and has undergone a series of design refinements. See Figure 2.

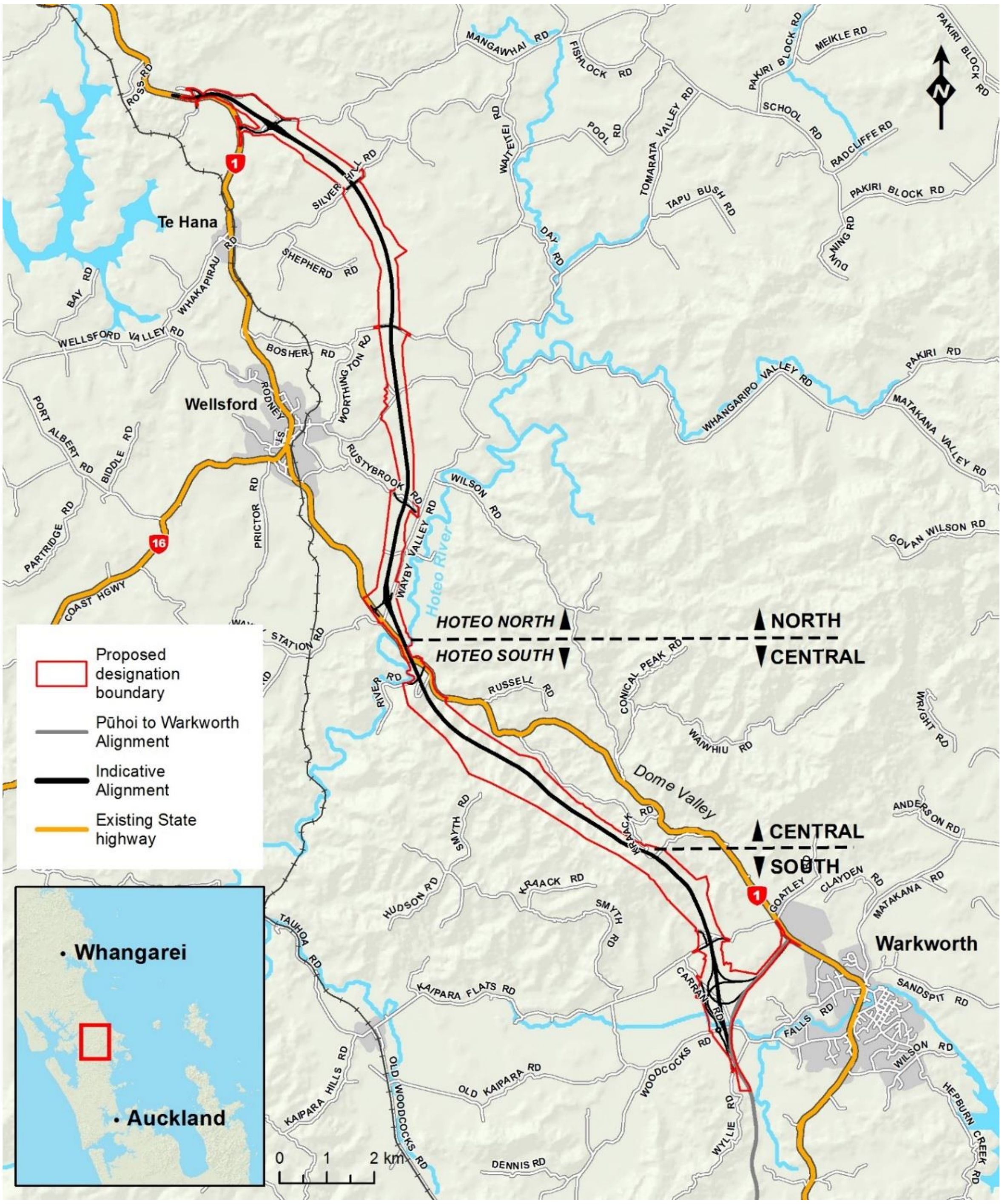

Figure 2 Project Sections and Indicative Alignment

The final alignment for the Project will be refined and confirmed at the detailed design stage through conditions and outline plans of works and in compliance with conditions. For that reason, the design of the various stormwater measures has been undertaken in response to the design of the Indicative Alignment within the proposed designation boundary area.

The recommendations we propose for the operational water design have been developed to mitigate against adverse effects and with reference to relevant design guidelines and standards. Stormwater measures will be subject to further design refinements within the proposed designation boundary at the future detailed design stage.

This report describes the various operational water measures, including cross drainage structures, proposed to collect, convey and treat stormwater flows in the operational phase of the Project and describes the methods and practices to be implemented to minimise environmental effects.

The structure and content of this report is as follows:

- **Section 1** – We describe the Project and the content of this report.
- **Section 2** – We describe the existing environment and the factors that influence stormwater flows, such as climate and rainfall, topography and geology.
- **Section 3** – We discuss the stormwater design philosophy, the principles adopted for the Project and the stormwater design guidelines and standards applicable to the Project.
- **Section 4** – We discuss the specific stormwater design response to the Indicative Alignment and the measures required to plan, design, operate and maintain the various stormwater systems included in the Project.
- **Section 5** – We present our recommendations and conclusions made on the stormwater design.

1.4 Overview of operational water management systems

In the context of the Project, operational water management refers to the management of stormwater flows during the operational phase (i.e. post construction period) of the Project. Whilst there may be similarities in the way stormwater flows are managed during construction, operational water management is separate from the works discussed in the Construction Water Management – Design Report.

Figure 3 provides a pictorial representation of how stormwater flows are managed and treated prior to discharge to the receiving environment during the operational phase of the Project.

Rainfall onto cuts and impervious surfaces is collected and conveyed to stormwater treatment devices prior to discharge to streams, which then subsequently drain to the estuaries and harbours.

Rainfall onto adjacent land (outside of the Indicative Alignment) is diverted away from cuts and the road and is discharged to existing streams and watercourses.

Meanwhile streams and watercourses that intersect the Indicative Alignment are passed through the road alignment by culverts or bridges. The Project's location and associated culverts often require stream diversions to facilitate construction of the road and culvert. In some circumstances (not shown in Figure 3) the Project's fill embankments will occupy existing floodplains.

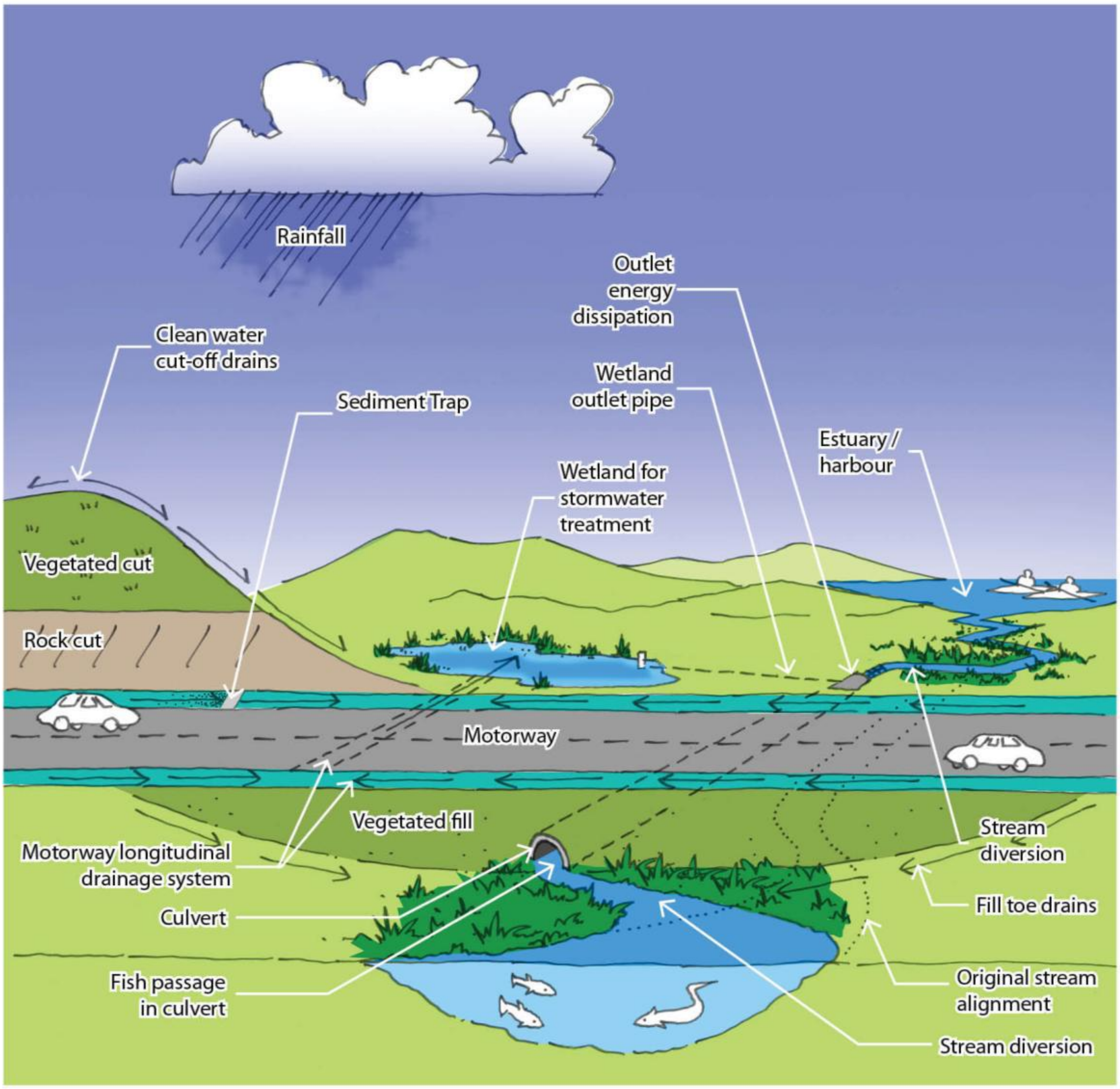

Figure 3 - Operational Stormwater Management Systems and the Environment

2 EXISTING ENVIRONMENT

In this section, we briefly describe the existing environment to provide a context for the indicative operational water design and subsequent assessment of effects. The section includes descriptions of the main river catchments, topography, geology, flooding and existing infrastructure. Additional detail relating to the existing environment can be found in the Water Assessment Report.

2.1 Catchment description

Following the Indicative Alignment from the south to the north it passes through the Mahurangi River catchment, crossing the left branch of the river. The Indicative Alignment then passes through the Hōteo River catchment, crossing many tributaries as well as the main channel of the Hōteo River near the existing SH1 crossing.

The Indicative Alignment continues north and crosses two tributaries of the estuarine Oruawharo River that are the Te Hana Creek and Maeneene Stream before tying back into the existing SH1 just north of Te Hana township.

The Indicative Alignment and associated catchment boundaries are shown on Figure 4.

The Mahurangi River is the main tributary of the Mahurangi Estuary, a long estuary flowing southwards from Warkworth on the eastern coast. There are many small bays and estuaries along the sides of the estuary with two larger arms to the south. Many of the small bays and upper estuaries dry during the tidal cycle and are comprised of soft muddy sediment.

The Hōteo River drains to the southern part of the Kaipara Harbour. Te Hana Creek and Maeneene Creek are tributaries of the Oruawharo River, which flows into the northern Kaipara Harbour.

The Kaipara Harbour is a complex drowned-valley enclosed estuary on the west coast of the Northland peninsula (Gibbs et al., 2012). The harbour is composed of intertidal flat and shallow sub-tidal habitats with deep channels following historic rivers. Sand barriers form north and south heads as well as tidal deltas, beach and dune systems.

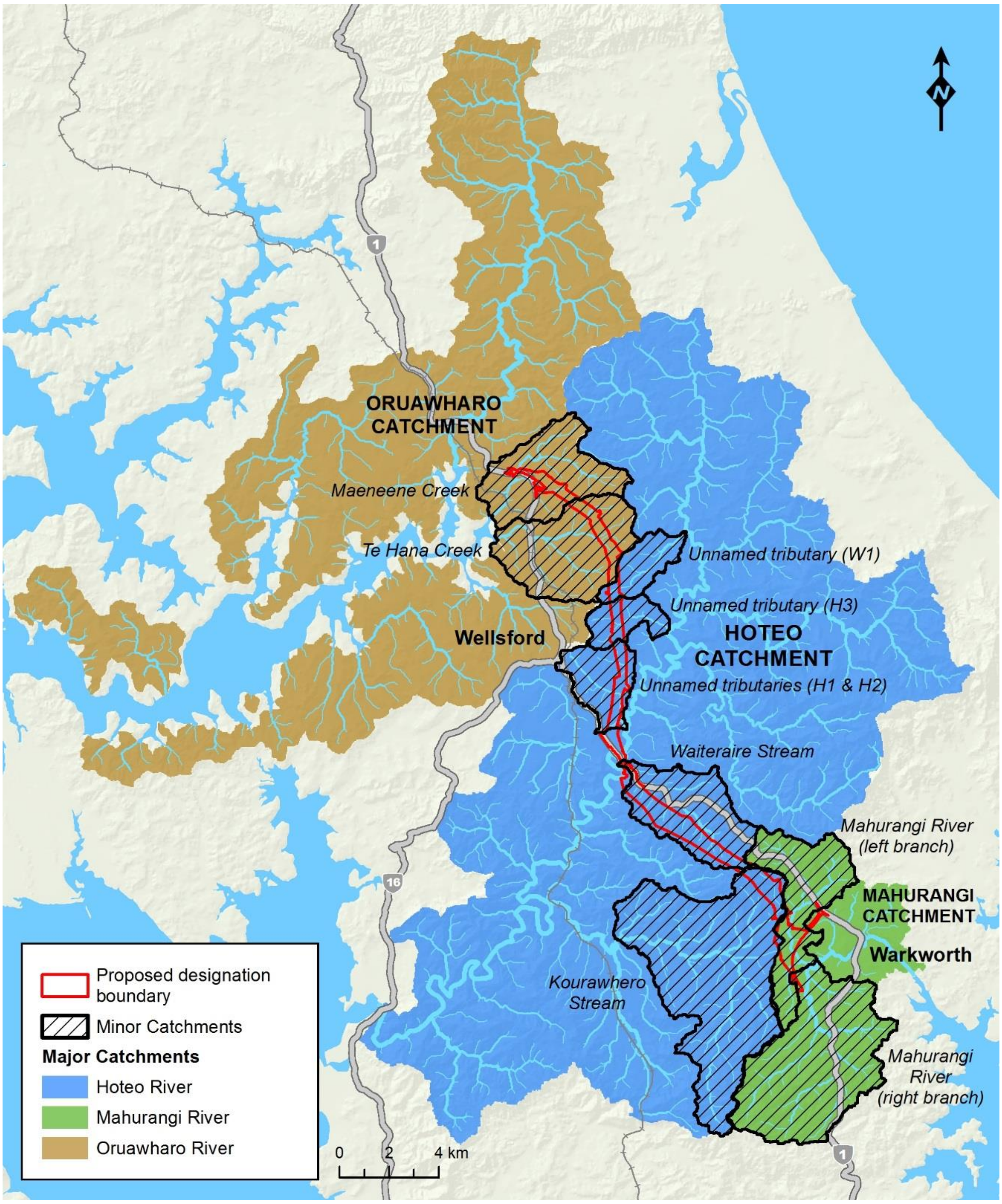

Figure 4 - Catchment boundaries.

2.2 Existing infrastructure

2.2.1 Mahurangi catchment

In the Mahurangi catchment there are bridges on Woodcocks Road, Kaipara Flats Road, Falls Road and the existing SH1, which cross tributaries/main branches of Mahurangi River, the flow in which are unaffected by the Project. When the Project is operational, the existing infrastructure will also include the P-Wk project currently under construction.

2.2.2 Hōteo River catchment

In the Hōteo catchment there is additional downstream infrastructure, including existing bridges and culverts, however these are generally outside of the proposed designation. From the south to the north below is a list of the downstream infrastructure:

- Culverts beneath Kaipara Flats Road on the Kourawhero Stream and its tributaries;
- Culverts on tributaries which flow beneath the existing SH1 on tributaries of the Waitarare Stream;
- The Project crosses the Hōteo River immediately upstream of the existing SH1 bridge crossing of the Hōteo River;
- Further downstream on the Hōteo River there are three crossings by the North Auckland rail line, the Tauhoa Road bridge and the SH16 bridge adjacent to the river mouth;
- Culverts beneath Wayby Valley road (tributaries of the Hōteo);
- A culvert beneath Whangaripo Valley road (tributary of the Hōteo);
- Two culverts beneath Worthington Road and Hindle Road (tributary of the Hōteo river) which lie beneath the Indicative Alignment; and
- One culvert beneath the Waiteitei Road (tributary of the Hōteo River).

Water Supply for Wellsford and Te Hana is also provided by Watercare from the Hōteo River. The water abstracted from the Hōteo River is treated to meet drinking water standards. Watercare has advised that they are in the process of investigating a potential change from the surface water supply to groundwater abstraction for the Wellsford and Te Hana water supply.

2.2.3 Te Hana Creek catchment

In the Te Hana Creek catchment there is existing infrastructure comprising a culvert at Silver Hill Road, and two bridges in Te Hana: the SH1 road bridge and the North Auckland rail line.

2.2.4 Maeneene Stream catchment

In the Maeneene Stream catchment the Indicative Alignment ties into the existing SH1 road alignment, and as such the Project overlies a series of existing infrastructure, this includes five existing culvert crossings of SH1 and a culvert beneath Mangawhai Road. The rail crossing of the Maeneene Creek is downstream of the Project.

2.3 Topography

The topography across the Project area ranges between approximately 15–300 metres Above Datum (mAD), with slopes ranging from 0–50 degrees.

The topography of the Project area can be divided into three distinct topographic areas depending upon the slope, with the generally flat lower Mahurangi River valley to the south between Woodcocks Road and Philips Road, the Dome ranges in the south, low undulating hill country in the centre and north.

The details of these are contained in Table 1 and shown on Figure 5; the data shown is based upon LiDAR data.

Table 1 – Topographic areas in the Project area

Area	Slope (degrees)	Elevation	Classification
Mahurangi River valley	Generally 0–10°, minor hills of 10–18°	30–85 mAD	The alignment south of the Kourawharo River (47200–50800 chainage)
Dome ranges	10–50°, multiple peak and valleys	40–300 mAD	Kourawharo River crossing to the Hōteo River crossing (38200–47200 chainage)
Wellsford flats	Generally 0–10°, regular hills 10–21°, peaks up to 30°	15–110 mAD	Area to the north of the Hōteo River crossing (0–38200 chainage)

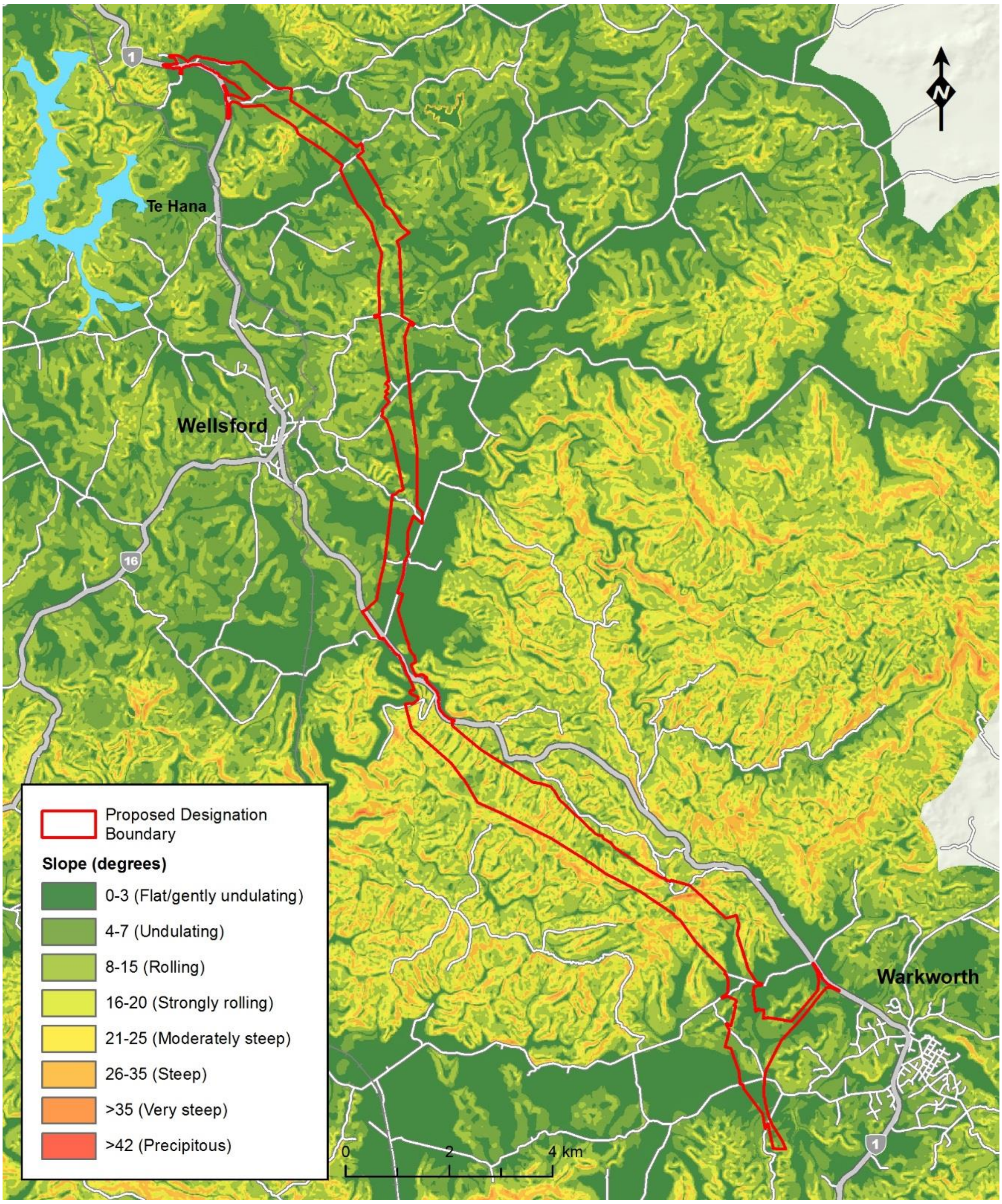

Figure 5 – Slope (in degrees) within the Project Area

2.4 Geology

A description of the geology in the Project area is presented in the Section 3 of the AEE, and has been summarised below. The regional geology is illustrated in Figure 6.

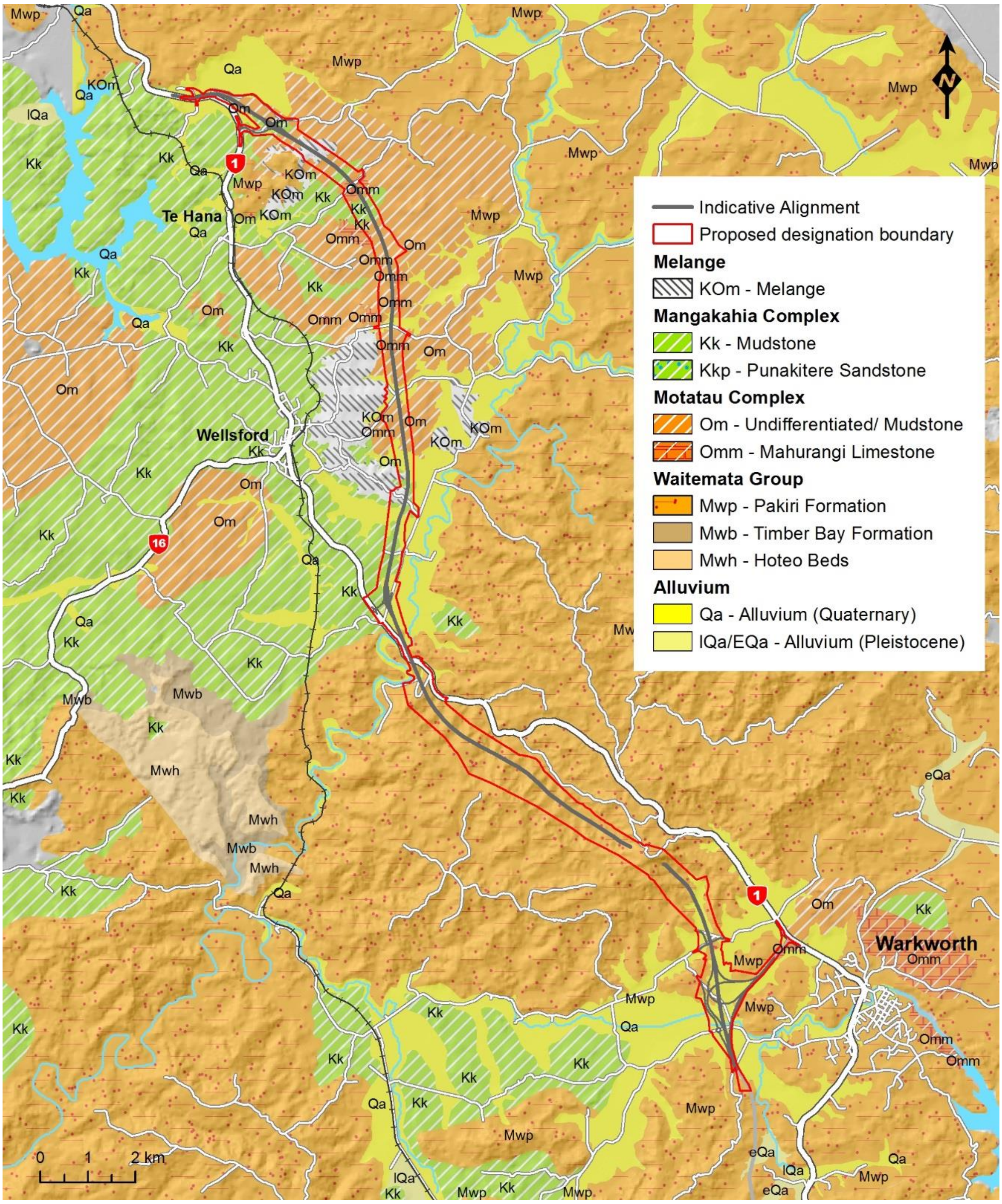

Figure 6 – Regional Geology

The Project area is predominantly underlain by sedimentary rocks of the Waitemata Group (Pakiri Formation) south of the Hōteo River, and the Northland Allochthon (formally known as Onerahi Chaos) rocks to the north of the Hōteo River. A description of the geology in the Project area is presented in the Section 3 of the AEE and the geology of the Project area is indicated in Figure 6.

The steep terrain within the central zone of the Project results in much of the overlying soils being either unstable or highly susceptible to erosion when exposed to certain climatic and ground cover conditions.

These conditions need to be considered for the Project's operational water management systems, as they are on the Northern Gateway Toll Road (NGTR) (immediately south of the Johnstone's Hill tunnels), where ongoing sediment has been observed to be generated from exposed cut batters in Pakiri Formation material after construction, which is evidenced in a number of the operational stormwater ponds and rock lined swales along this section of completed state highway which require additional and/or increased frequency of inspection and maintenance operations to be carried out.

3 OPERATIONAL WATER – DESIGN PHILOSOPHY AND REQUIREMENTS

This section discusses the operational water design philosophy, the stormwater design requirements and standards/guidelines applicable to the Project.

3.1 Operational water design philosophy

The operational water design philosophy adopted for all design stages of the Project has been selected to manage the potential effects from operational stormwater runoff due to increase in flows, volumes and contaminants as follows:

- The design will provide a best practicable option to avoid, remedy or mitigate adverse environmental effects, determined through a robust evaluation of the Project proposals in line with the NZ Transport Agency's and Auckland Council's requirements relating to the design and construction of stormwater conveyance and treatment systems.

- The design will include full consideration of, and respond to, the implications of stormwater management throughout the design life of the Project and will integrate the stormwater collection and conveyance networks, treatment devices, culverts and watercourse diversions and have due consideration of existing floodplains to ensure potential adverse effects relating to stormwater discharges are minimised.

- The design will take cognisance of and where practicable address existing environmental issues and environmental sensitivities to deliver outcomes that avoid, remedy or mitigate adverse environmental effects.

- Where possible, the design will avoid or mitigate changes that may make the current flood issues in the catchment worse.

- The design will as far as is reasonably practical, provide for habitats in stream diversions where they existed prior to the Project which may include restoring streams and natural habitats.

- The carriageway level will be set at a freeboard above predicted 1 in 100 year flood levels. Carriageway stormwater runoff flows and volumes will be managed to provide safe serviceability of the road in the required design rainfall events.

- Outfalls will be assessed on a case by case basis and where required will incorporate erosion control measures that do not impede fish passage.

- Where required, the design will provide for fish passage in culverts for all permanent streams with upstream habitats, and for intermittent streams where there is the potential for fish habitat upstream.

- The design will be undertaken to ensure that the Project will not cause an increase in flood risk at existing habitable floor levels.

- Overland flow paths will be provided and maintained, for flows in excess of the primary drainage network capacity to allow for flows up to and including the 100 year ARI storm.

- The design will include a range of water sensitive design solutions (in accordance with the Auckland Unitary Plan Operative in Part (AUP(OP)) and Transport Agency standards) including treatment swales and treatment wetlands to deliver stormwater hydrology (flows and volumes) and stormwater quality (treatment) mitigation.

- Vegetated stormwater treatment systems are preferred over traditional "channel and pipe" approach, and a best practical option approach will be needed, which recognises the range of activities, and constraints of the existing environment and land use and motorway operation.

- Water quality treatment should be achieved through the design and construction of stormwater treatment devices, which will target the removal of suspended solids and contaminants of concern including Zinc, Copper and other persistent and bio-accumulative contaminants.

The application of the operational water design philosophy to the Project is described in the Water Assessment Report.

3.2 Stormwater design guidelines and standards

The following is a list of the various stormwater related guidelines that should be applied to the Project, we note that Auckland Council guideline TP10 has been superseded by GD01 issued December 2017, However the AUP(OP) makes reference to TP10 and therefore, for completeness, TP10 has been included in the list of guidelines below:

- Auckland Unitary Plan (Operative in Part) in particular:
    - E1 Water quality and integrated management;
    - E8 Stormwater – Discharge and diversion;
    - E9 Stormwater quality – High contaminant generating car parks and high use roads; and
    - E10 Stormwater management area – Flow 1 and Flow 2.
- Auckland Council – Stormwater Management Devices in the Auckland Region; December 2017; Guideline Document 2017/001 Version 1 (GD01).
- Auckland Council – Water Sensitive Design for Stormwater; March 2015 Guideline Document 2015/004 (GD04).
- Auckland Council Code of Practice for Land Development and Subdivision Chapter 4 – Stormwater (ACSWCoP).
- Auckland Regional Council (ARC) Technical Publication 10 Stormwater Management Devices: Design Guidelines Manual (TP10).
- ARC, Technical Publication 108 Guidelines for Stormwater Runoff Modelling in the Auckland Region (TP108).
- Auckland City Council, Soakage Design Manual, 2003.
- AS/NZS 2566 Buried Flexible Pipelines, 1998.

- AS/NZS 3500.3, Plumbing and Drainage Part 3: Stormwater, 2003.
- AS/NZS 3725, Design for Installation of Buried Concrete Pipes, 2007.
- Stormwater Treatment Standard for State Highway Infrastructure, 2010, NZ Transport Agency.
- NZ Transport Agency: Bridge Manual (Bridge Manual) 3rd edition (SP/M/022-2013).
- NZ Transport Agency: P46 Stormwater Specification; April 2016.
- NZ Transport Agency: TNZ Highway Surface Drainage: A Design Guide for Highways with a Positive Collection, 1977.
- Austroads Waterway Design, 1994.
- Auckland Transport Code of Practice 2013 (Chapter 17 – Road Drainage) – (ATCOP).

3.3 Operational water management

The operational water management for the Project falls into two broad categories of water quality and water quantity as discussed below.

3.3.1 Water quality

Water quality refers to the treatment of stormwater runoff to remove suspended and physical contaminants generated from new or modified impervious surfaces associated with the Project through the provision of stormwater treatment devices at appropriate locations along the Indicative Alignment.

We propose the following water quality treatment on the Project in order to meet the AUP(OP) standards:

- Water quality treatment to be provided for all new and modified impervious areas, which includes the modified local roads, new motorway impermeable surfaces and rock cuts;
- Stormwater treatment design based on GD01 requirements, which for wetlands are to capture and treat the water quality volume that equates to the runoff volume of the 90th percentile storm. This requirement targets the removal of contaminants of concern such as suspended sediment, copper, zinc along with particulate nutrients, oil, grease and bacteria; and
- Removal of gross litter and floatables including oil and volatile hydrocarbons.

3.3.2 Water quantity

Water quantity design refers to the design of stormwater collection, conveyance and detention systems, including the collection of stormwater runoff from impervious surfaces, which is then discharged to the various stormwater treatment devices where hydrology mitigation and stormwater detention measures will also be provided, prior to it being discharged to the receiving environment.

Water quantity design also includes for the provision of stream diversions and culverts to pass flows from existing catchments upstream through or around the final alignment.

The proposed requirements for water quantity management, which we recommend as conditions of the Project, are summarised below:

- Provision of a stormwater collection and conveyance systems that are consistent with NZTA P46 AUP(OP);

- Provision of stream diversions around or through the Project, via culverts or bridges;

- Hydrology mitigation consistent with the AUP(OP) standards (Chapter E10) by providing detention of the increase in volume generated by the 95th percentile rainfall event on the Project's impermeable surfaces, which is then released to the receiving environment over a 24-hour period.

3.4 Specific design requirements

Sections 3.4.1 to 3.4.3 discuss the specific requirements used in the indicative design of the various operational water management features for the Indicative Alignment.

3.4.1 Hydrology for cross culverts and Bridges

We have used the TP108 graphical method to determine the rainfall values for the 1% AEP and 10% AEP peak flows for sizing the cross culverts for the Project.

The TP108 parameters used are as follows:

- Areal reduction factors: selected based on catchment size, as per TP108. However, these are only required for catchments greater than 10 km2.

- Time of concentration: Have been calculated using the TP108 equation using a channelization factor of 0.9 and catchment length and slope using 1 m contour mapping provided by Auckland Council. A minimum time of concentration of 10 minutes has been adopted.

- Initial abstraction: 0 mm for urban areas and 5 mm for pervious areas.

- SCS soil group: The soil of the Project area was defined using the GIS-based NZLRI soil maps of Landcare Research.

- Curve number: Assigned using tables supplied in TP108 and related to the land use categories from LCDB4.

- Rainfall depths: derived from TP108 isohyet maps and increased for climate change by multiplying rainfall depths with factors provided in Table 2.

Incorporating the impacts of climate change on peak flows

The effects of climate change on peak flows as at 2130 have been incorporated into the design hydrology. The year 2130 has been selected as this allows for 100 year of climate change effects after the Project construction commencement date of 2030, to be incorporated into the design.

With respect to climate change adjustment factors, we have followed Auckland Council's Code of Practice for Land Development and Subdivision (2015). The climate change adjustment factors used have been derived from the information provided in MfE (2010)[1], based on a mid-range climate change temperature increase scenario to 2090 from the IPCC fourth assessment.

We have linearly extrapolated the predicted temperature increase to 2130, which assumes an 8% increase in rainfall intensity per 1°C increase in temperature (MfE, 2010), and the climate change adjustment factors used in the stormwater design for calculating design flows are provided in Table 2 below.

Table 2 – Climate Change Adjustment Factors

Climate Change Adjustment Factors (MfE(2010)				
ARI (Year)	**2**	**10**	**20**	**100**
Increase to Rainfall Depth (percentage)	14.2	20.8	23.8	26.4

The MfE (2016)[2] guidance provides revised estimates for climate change, which are lesser than those predicted in the fourth assessment which was used in the Auckland Council's Code of Practice for Land Development and Subdivision (2015) and we have provided a comparison of the predictions between the fourth and fifth assessments in Figure 7 below.

The MfE (2016) guidance has been used in the assessment of flood effects and testing bridge freeboard for the Indicative Alignment and the MfE (2010) guidance has been used in the design of the various stormwater elements discussed in the body of this report and will provide for conservative design proposals.

1 MfE (2010): Ministry for the Environment Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fourth Assessment

2 MfE (2016): Ministry for the Environment Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment

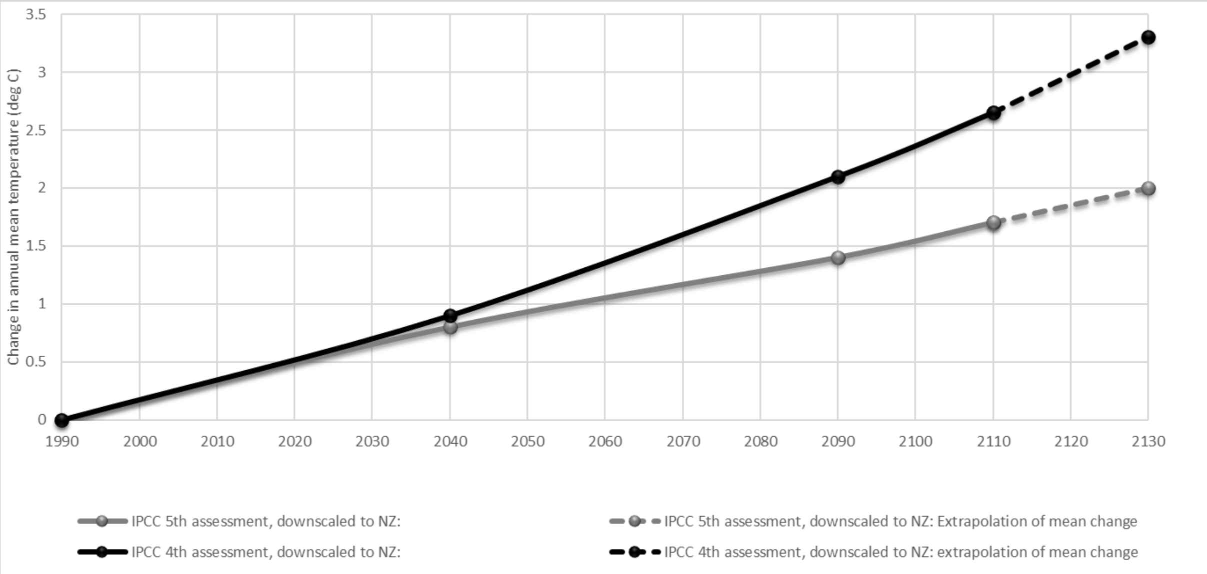

Figure 7 – IPCC 4th and 5th assessment of climate change temperature change downscaled for New Zealand

Hydrology for Bridges

The hydrological methods for the flood assessments are described in Flood Modelling Report and are summarised below:

- Mahurangi TP108 with 16% increase in rainfall to account for climate change at 2130 (IPCC 5th assessment).
- Kourawhero TP108 with 16% increase in rainfall to account for climate change at 2130 (IPCC 5th assessment).
- Hōteo Flood Frequency with 26.4% increase in peak flow to account for climate change at 2130 (IPCC 5th assessment).

The bridge crossings of watercourses included in the Indicative Alignment have more than 1.2 m of freeboard when compared to the predicted flood levels and the Geometric design rather than hydrological considerations have been the determining factor for the soffit levels for these bridges included in the Indicative Alignment.

The predicted 100 year ARI event flood levels at bridges, 5, 6 11 and 22 are provided in Table 3.

Table 3 – Indicative Bridge Flood Levels

Indicative 100 year ARI event flood levels summary			
Bridge	**Length (m)**	**Soffit Level (m)**	**Predicted Flood Level (m)**
Bridge 5	65	40.2	36.78
Bridge 6	110	41.0	37.24
Bridge 11	490	41.38	27.850
Bridge 22	96	63.82	54.05

Bridge 20 across the Maeneene stream has not been assessed at this stage of the Project as this bridge is currently designed with a span of approximately 100 m with a soffit level greater than 4 m above the floodplain and therefore there is sufficient clearance and freeboard above predicted flood levels. Further assessment is documented in the Flood Assessment technical report.

The Bridge Manual design criteria would require scaling the site flood frequency estimates for Auckland Council's flow monitoring sites on the Hōteo and Mahurangi Rivers, which is in accordance with Section 2.3.3 of the NZTA Bridge Manual, and is likely to generate lower estimates of flood flows than the TP108 analysis that has been undertaken for some rivers at this stage of the design.

We have compared flow estimates using TP108 with the flood frequency analysis as follows:

- Rainfall depths, derived from the TP108 isohyet maps, have been checked using depth-duration-frequency estimates from a rain gauge located within the Hōteo catchment. This indicated that the TP108 24-hour rainfall depths for the 100-year ARI event provide higher rainfall values than have been recorded therefore the values used in the design would provide higher design peak flows than have been recorded by the rain gauge and we would therefore consider that the design is conservative and will be subject to further refinement at future stages of the design.

- Modelled peak flows (using TP108) for the Waiwhiu Stream were compared to flood frequency analysis results at the NIWA monitoring site 'Waiwhiu at Dome Shadow'. This check indicated that the 100 year ARI event peak flows derived using TP108 would be approximately 22% higher than those derived using at-site analysis. Therefore we consider that the design of the cross culverts would be conservative and would be subject to further refinement at future stages of the design.

- Modelled peak flows allowing for climate change result in a 100 year ARI flow of 615 m^3/s (using TP108) for the Mahurangi River. This flow was compared to flood frequency analysis results within the Auckland Council supplied hydraulic model at the Mahurangi College flow monitoring site, (which do include an allowance for climate change effects) which provides a 100 year ARI event flow of 278 m^3/s. Therefore, the design peak flows for the flood analysis and bridge freeboard assessment on the Mahurangi River are likely to be conservative.
- As documented in Auckland Council's report, the peak of 100 Year ARI event without an allowance of climate change is 278 m3/s, which was estimated by flood frequency analysis of College gauging site records. While the hydraulic model was developed by following the methodology as described in TP108 that produced a peak of 615 m3/s for 100 Year ARI event with an allowance of climate change at the same location.

3.4.2 Cross drainage and overland flow paths

Cross drainage structures, including culverts and bridges, are to be designed to allow the continued flow of existing watercourses and overland flow paths with minimal hydrological differences to the surrounding environment and will generally be in the form of pipe or box culverts or viaducts or bridges.

Culverts (pipe or box)

Culvert crossings should maintain the existing natural drainage patterns of the contributing catchment where possible, such that existing flooding is not exacerbated nor new flooding issues created. Crossings must not concentrate several watercourses into one discharge point where this will result in unacceptable adverse effects

To achieve these outcomes, all culverts and pipe crossings in the final design (existing and new) that cross the state highway will need to satisfy the following hydraulic criteria:

- Convey the 10 year ARI storm event flow without surcharge of the pipe for the Maximum Permitted Development (MPD) scenario.

- Convey the 100 year ARI storm event flow without surcharge of the pipe more than 2m above the pipe soffit, whilst ensuring a minimum 500mm freeboard is provided from the peak water level to the outer road edge level for the MPD scenario.

- All new culvert structures and pipe crossings under local roads be designed in accordance with Auckland Council's Stormwater Code of Practice.

- Cross culverts in wooded or urban catchments be checked for blockage risk in accordance with the Australian Rainfall & Runoff (2015), Blockage of Hydraulic Structures – Blockage Guidelines or approved alternative methodology.

- Where the debris potential is determined to be medium or high, debris countermeasures to be designed in accordance with the Blockage Guidelines and where required secondary inlets should be provided to maintain the culvert headwater requirements. Where a risk of blockage remains and/or the consequences are high, works to be included to divert overflows that might occur so they remain within the road reserve until entering another watercourse.

- Embankments are not dams as per the Building Act Definitions, but may need to be designed for the retention of water in the event of a blockage to a culvert and the design of the embankments must include consideration of storm event scour, overtopping, embankment stability (including rapid drawdown conditions) and the potential for piping failure.

Bridges and viaducts

To meet design standards bridges and viaducts should be designed to cater for the 1 in 100 year ARI event flows storm and depending on the importance level of the structure, a scour assessment undertaken to check for scour against the 2,500 and/or 5,000 year ARI storm in accordance with the NZ Transport Agency's Bridge Manual to determine if additional protection measures are required.

For the 100 year ARI event, to reduce the risk of blockage at bridges and viaducts the freeboard requirements should be a minimum of 600 mm in non-forested areas and 1,200 mm in forested areas. The larger freeboard requirement for forested areas reflects the greater risk of blockage due to fallen logs and branches.

Fish passage

At this stage of the design process, we have assumed that fish passage will be required in all culverts and this will be confirmed by the Project's ecologists in future stages of the Project's design.

Where required, fish passage provisions should be designed and provided in accordance with Auckland Council's Technical Publication 131.

Overland flow paths

Overland flow paths, should be designed to cater for a 100 year ARI event. However, where no secondary flow route/overland flow path is available then the capacity of the primary stormwater collection system will be designed to cater for the 100 year ARI rainfall event.

3.4.3 Edge collection systems

Longitudinal drainage systems

Longitudinal drainage should be designed to collect rainfall events up to the 1 in 10 year ARI event flow (Q_{10}) from all road pavements. Where no overland flow path is available to cater for the 1 in 100 year ARI event flows the primary stormwater collection system will be designed to cater for the 1 in 100 year ARI event.

Fills

The stormwater collection system at the outer edge of fill embankments shall prevent stormwater from flowing over and down the face of the fill embankments.

Cut slopes

Swales or open drains shall be provided adjacent to the road at the base of all cut batters. These will be designed to convey flows in excess of any pavement collection system and will be designed to cater for the 100 year ARI event.

Cut-off drains

Cut-off drains shall be included at the top of all cut slopes and the bottom of fill slopes to prevent stormwater flows from the natural catchment uphill of the alignment from flowing down the cut face or flowing along the toe of fill batters. These cut-off drains should be sized as a minimum to convey the 100 year ARI storm event from the upstream catchment.

Medians

In accordance with the NZ Transport Agency's stormwater specification (P46), on superelevated sections of a 4-lane state highway, surface water should be captured at the high side of the central median to prevent water flowing from one side of the road to the other. Collected stormwater should be discharged to an appropriate stormwater treatment system.

Median drains should be designed to cater for a 10 year ARI rainfall event.

Bridges and viaducts

For road safety, bridges and viaducts should be designed to ensure that stormwater runoff does not encroach onto a live traffic lane during a 10 year ARI rainfall event, otherwise they should incorporate a positive drainage system which should be designed to cater for a 10 year ARI rainfall event.

Stormwater runoff from all bridges and viaducts should be discharged to one of the Project's stormwater treatment devices.

4 OPERATIONAL WATER – DESIGN APPROACH

This section provides an overview of the operational water systems for the Indicative Alignment. It describes the approach that has been used to meet the philosophies and design requirements discussed previously in this report. The specific operational water systems for the Indicative Alignment are shown in the Drawing Set: Stormwater Drawings (Volume 3 of the AEE).

4.1 Operational water design

Sections 4.1.1 to 4.1.9 describe the various components of the Project's indicative stormwater collection, conveyance and treatment systems considered to be appropriate for use in the final design of the Project.

4.1.1 Cut-off drains

Cut-off drains are provided above cut sections and at the toe of fill sections of the Indicative Alignment to divert stormwater runoff from the natural catchment which falls towards the Indicative Alignment.

Cut-off drains have been designed to cater for the 100 year ARI rainfall event for the upstream catchment and will either discharge to existing streams, watercourses or to new culverts, or to the road edge conveyance system where this is not possible.

In order to prevent scour and erosion of the cut-off drains, these will be grassed or rock lined channels and on steeper slopes (>5%) rock check dams will be introduced to reduce velocities within the channel.

The location of the proposed cut off drains associated with the Indicative Alignment and a typical detail of a cut-off drain are shown in the Drawing Set: Stormwater Drawings (Volume 3 of the AEE).

4.1.2 Stormwater reticulation (collection and conveyance systems)

Stormwater reticulation, at the road edge, has not been designed for this phase of the Project as it is not material to the consent applications.

In future stages of the design the stormwater reticulation will convey stormwater runoff from the Project's impermeable surfaces and cuts to stormwater treatment devices.

Indicative stormwater reticulation has been included in the drawing cross sections (Volume 3 of the AEE) in order to inform the designation footprint required by the Project.

Future stormwater reticulation may include the following types:

- Kerb/channel/catchpit/pipe;
- Drainage channels/swales;

- Rock trap drainage channels; and
- Inlet and outlet structures (i.e. inlets and outlets from wetlands, from motorway and/or streams).

The road collection and conveyance systems should collect stormwater from new or modified impervious surfaces and rock cuts and should be designed to cater for a 1 in 10 year ARI rainfall event without surcharge and should convey stormwater runoff to the stormwater treatment wetlands located at appropriate locations along the Project.

In areas of the Project where a kerb and channel is required as part of the road design, catchpit inlets discharging to underground pipework should be provided at appropriate centres.

In accordance with Section 4 of the NZ Transport Agency's Stormwater Specification P46, on median divided roads of four or more lanes, surface water is not permitted to flow from one side of the road to the other (including gore areas and superelevated sections of state highway). In order to meet this criteria a longitudinal drain will need to be provided in gore areas or central median drain in superelevated sections of road to collect stormwater runoff. The stormwater runoff from these areas discharges to underground pipework via catchpit inlets and is then discharged to the road edge conveyance systems and subsequently onto a stormwater treatment device.

Where a kerb and channel is not required, stormwater runoff from impervious surfaces discharges to a vegetated or rock lined roadside drain or swales.

4.1.3 Vegetated or rock lined roadside drains

A number of local roads will be constructed, upgraded or modified as part of the Project as listed below:

- Curran Road;
- Woodcocks Road;
- Kaipara Flats Road;
- Philips Road;
- River Road;
- Wayby Valley Road;
- Rustybrook Road;
- Farmers Lime Road;
- Silver Hill Road;
- Mangawhai Road;
- Vipond Road;
- Maeneene Road; and

- Waimanu Road.

Conveyance of water runoff from these local roads will be via vegetated or rock lined swales, thereby providing stormwater treatment for the runoff from these local roads. These swales will then discharge to existing streams.

Roadside swales and open drains are commonly used around New Zealand and are generally "U" shape in profile. Their primary function is collection and conveyance of runoff. However research has shown that vegetated drainage channels are effective at TSS removal and achieve high removal rates of particulate and total copper and zinc.

These local roads have relatively low traffic volumes and we consider vegetated roadside swales to be appropriate for the conveyance and treatment of stormwater runoff from these areas.

4.1.4 Sediment traps

Sediment traps are proposed for the Project in drains at the base of rock cuttings. These sediment traps are bespoke treatment devices that will assist in the capture of sediment generated from rock cuts.

We consider sediment traps are required in the Project's design based on the experiences and observations of the operational phase of the NGTR project, where since becoming operational in 2009, the cut faces have yielded larger sediment loads than was anticipated during the design stage of the NGTR project, This increase in sediment has affected the performance of that project's stormwater treatment systems.

At the time of writing this report, sediment traps have been incorporated into the design and will also be adopted in the design for the adjacent P-Wk project to reduce the sediment eroded from the cut faces from reaching the stormwater treatment wetlands on that project.

A typical detail for a sediment trap is shown in the Drawing Set: Stormwater Drawings (Volume 3 of the AEE).

4.1.5 Stormwater treatment

Vegetated stormwater treatment systems (e.g. swales and constructed wetlands) are our preferred stormwater treatment device for the Project and will treat stormwater runoff from the Project's impervious surfaces totalling 198.2 ha.

Stormwater runoff will be collected in the Project's drainage systems, which will be conveyed by roadside drains, swales or underground pipes to the constructed wetlands.

The constructed wetlands will be designed in accordance with GD01, with a volume allowance made to allow for the hydrology mitigation requirements of the AUP(OP) and peak flow controls for the 2 year and 10 year ARI rainfall events.

It is anticipated that with further development of the Project design at future stages, the wetland locations and sizes will be further refined with consideration given to landscape, constructability, maintenance and ecological values.

The constructed wetlands will be located off-line from existing streams and watercourses and will not be located in or on the bed of an existing stream. Existing natural wetlands will not be used for the treatment of runoff from the Project.

Stormwater treatment wetlands

The indicative design for the Project includes 34 stormwater treatment wetlands. The rationale for the location of wetlands is as follows:

- Located to suit low points in the vertical alignment of the Indicative Alignment;
- Efficiently spaced to ensure consistent sizing and catchment sizes;
- Located close to the Indicative Alignment in order to minimise the overall Project footprint. Landscape fill along with soil disposal areas will be used as platforms for constructed wetlands for stormwater treatment. This reduces the overall footprint of the Project;
- Located out of the post-development 100 year ARI floodplain, wherever possible;
- Located close to the Indicative Alignment to provide convenient and safe access for maintenance; and
- Located to reduce conveyance of water across bridges and viaducts.

Wetland outfalls should be sized to cater for events up to the 10 year ARI flow rate and should incorporate an emergency overflow or bypass system that should cater for the 100 year ARI flow rate for the upstream catchment.

A pipe or open channel should be provided to discharge treated stormwater to the nearest available watercourse.

Wetland outfalls should incorporate erosion protection measures to minimise bed scour and bank erosion in the receiving waterway. Typically this protection would be through an energy dissipation device and/or rock aprons.

In many instances, the flow from the wetlands can be directed to the inlet or outlet of an adjacent culvert and would have the benefit of eliminating the requirement for the duplication of energy dissipation devices.

Indicative wetland locations are shown on the Drawing Set: Stormwater Drawings (Volume 3 of the AEE). Appendix A includes a summary of the indicative wetland sizes.

4.1.6 Stream diversions

Stream diversions are required where a natural stream channel will be affected by the construction of the Project or where it is necessary to connect an existing stream to a new culvert.

As culverts will normally be constructed offline in a dry environment and protected from flooding during construction, all new culverts require a minimum 10m of stream diversion upstream and downstream of the culvert to tie back into the existing stream. The offline construction methodology for culverts is described in the Construction Water – Design Report.

All stream diversions should be designed to cater for a 100 year ARI rainfall event and will convey flows to/from a culvert, beneath a bridge or to another stream or water body.

The objective of the stream diversion design is to recreate streams and habitats that replicate, as much as is practically possible, the natural state and habitats of the steams that existed prior to the Project becoming operational. The flow chart for selecting the stream diversion type required is shown in Figure 8.

Three stream diversion typologies are proposed as follows:

- Stream Diversion Type 1 – "Lowland Stream" that recreates habitats associated with a natural lowland stream.
- Stream Diversion Type 2 – "Steep Stream" that recreates habitats associated with a natural steep stream.
- Stream Diversion Type 3 – Flow Channel for flow conveyance only.

Typical details of these stream diversions are shown in Figures 8, 9 and 10 and the total lengths in the indicative operational stormwater design are summarised below:

- Stream Diversion Type 1 = 12,707 m
- Stream Diversion Type 2 = 5,554 m
- Stream Diversion Type 3 = 1,148 m

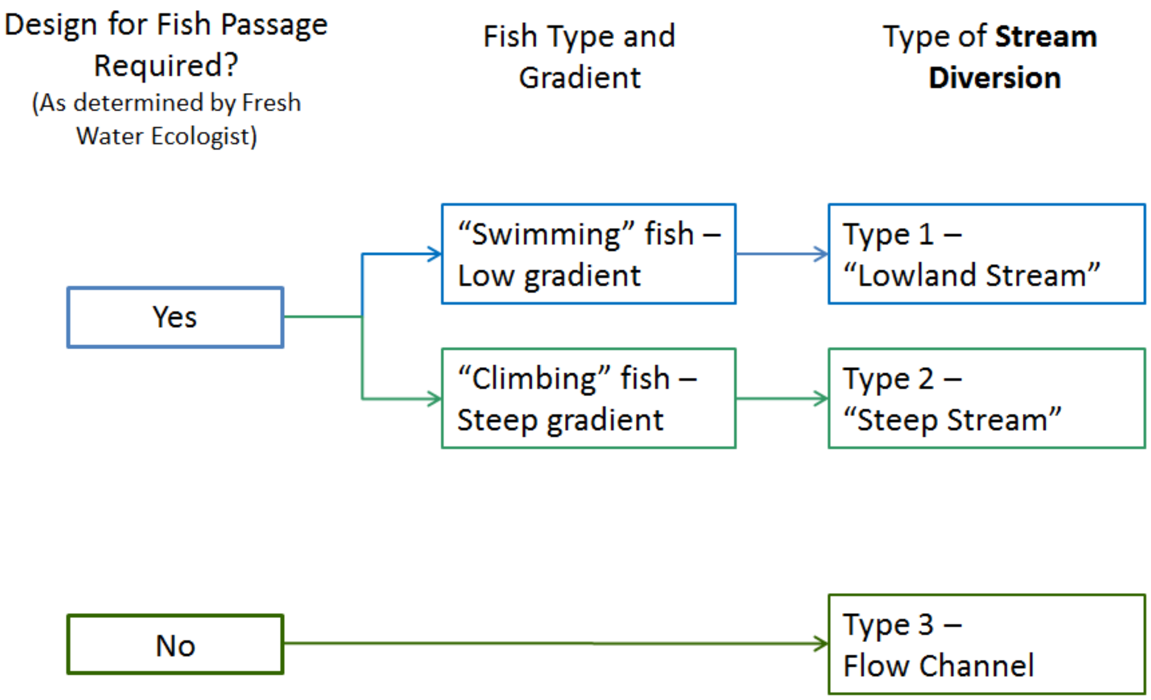

Figure 8 – Flow chart for stream diversion type

Fish passage will be required where there is currently fish habitat in or near the streams being affected, or where there is potential for future fish habitat. At this stage of the design, we have assumed that fish passage will be required in all these instances.

The stream diversion details as shown in Figure 9 to Figure 11 below were originally developed during the design of P-Wk in collaboration with the freshwater ecologists for P-Wk together with input from Hōkai Nuku. For the design of this Project we have adopted this same approach and have used the same stream diversion details.

The stream types used on the P-Wk project are considered to be appropriate for use on this Project and will be subject to further design refinement at detailed design stage.

Our starting principle for the design was to minimise adverse environmental effects by recreating habitats for stream diversions that restore streams to a natural state.

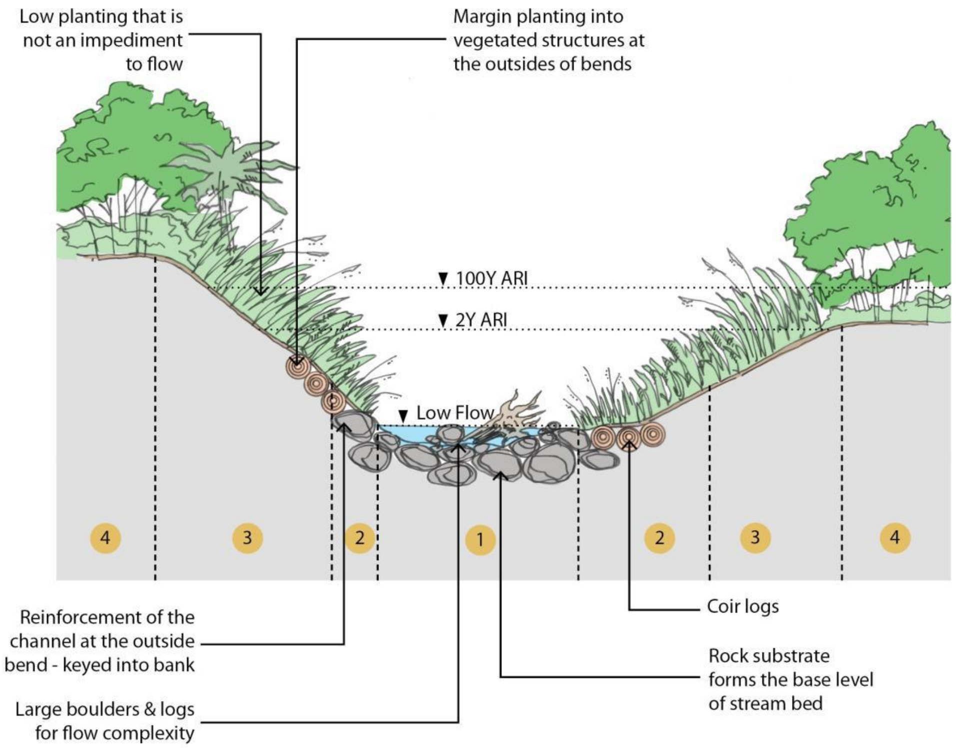

Figure 9 – Stream Diversion Type 1 – Lowland stream cross section

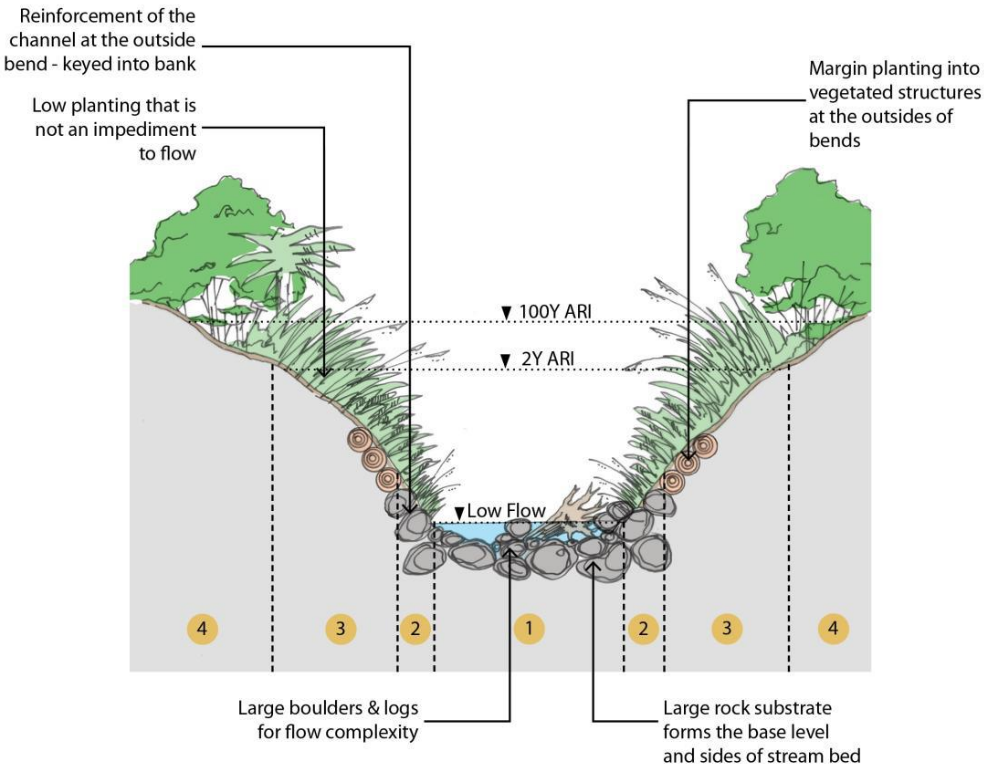

Figure 10 – Stream Diversion Type 2 – Steep stream cross section

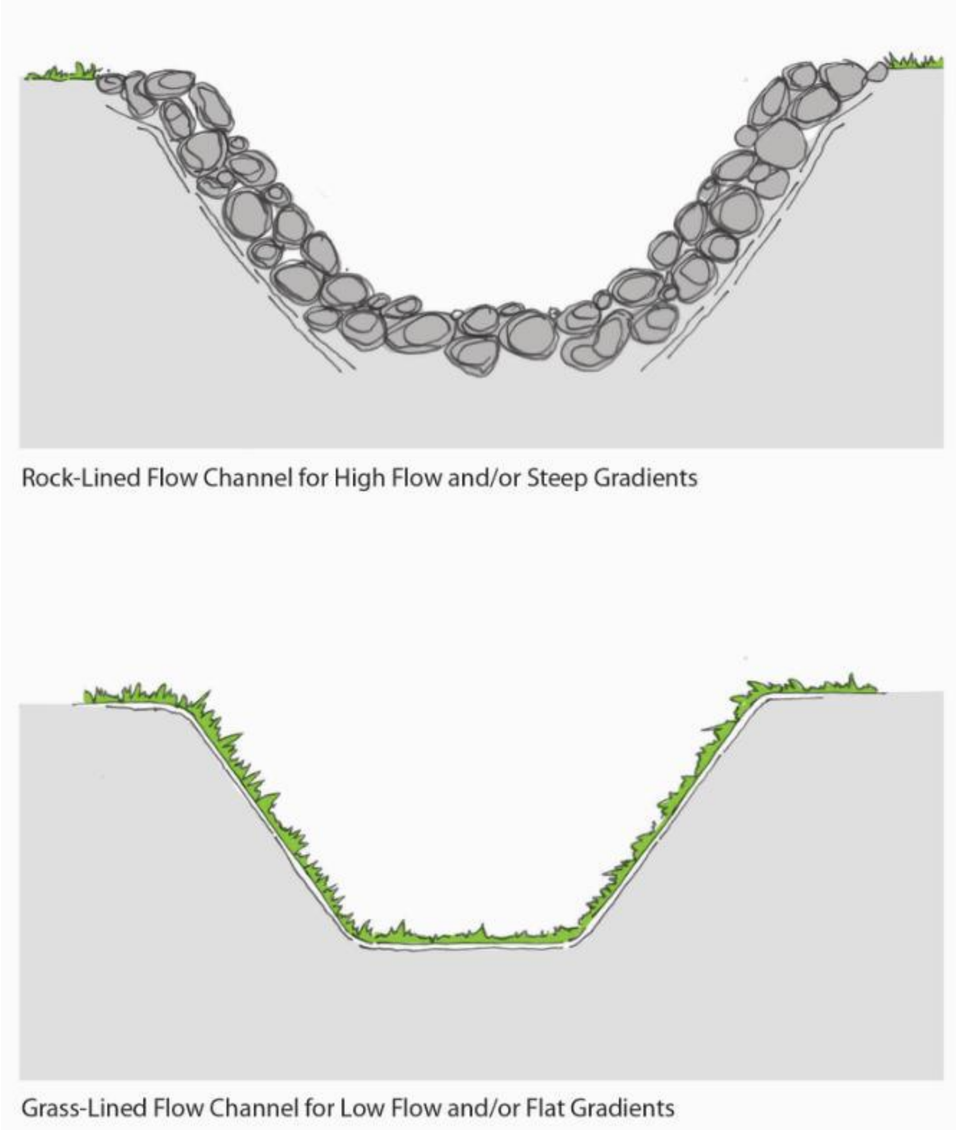

Figure 11 - Stream Diversion Type 3 - Flow channel cross section

4.1.7 Culverts

The need for and the indicative location of culverts were determined following an analysis of the upstream catchments using land-use maps, aerial images, LiDAR contour information, and the nominated soil disposal sites identified for the Project.

Each sub-catchment was delineated and separated into pervious and impervious areas for the hydrological calculations. The TP108 Graphical Method was adopted to establish peak flow rates for each catchment.

The sizing of each indicative culvert was determined using HY-8 culvert design software. The culvert sizes required for the Indicative Alignment were based on a range of hydraulic requirements and additional considerations for safety and maintenance as detailed in Table 4.

Table 4 – Culvert Sizing Criteria

Culvert Sizing Criteria	
Criteria	**Source**
Hydraulic Capacity: • Pass a 10 year ARI without Heading up • Minimum Freeboard of 500 mm to the edge of carriageway during a 1 in 100 year ARI event. • Headwater depth during a 100 year ARI event < 2 x Culvert Diameter	NZTA P46 Stormwater Specification
Debris Blockage: • In high risk catchments increase the culvert size to accommodate a 100 year ARI without heading up and provide debris rack upstream of culvert (Drawing SW-305); and • In moderate risk catchments provide a relief inlet (Drawing SW-306).	NZTA P46 Stormwater Specification
Minimum diameter for safety and maintenance purposes: • Culvert < 30 m length = Culvert to be 600 mm minimum diameter; • Culvert 30 - 100 m length = Culvert to be 1200 mm minimum diameter; and • Culvert > 100 m length = Culvert to be 1600 mm minimum diameter.	NZTA P46 Stormwater Specification
Minimum cover • Culverts should be provided with not less than 1,200 mm of cover.	NZTA P46 Stormwater Specification Austroads Guide to Road Design part 5 Drainage Design

Energy dissipation at culvert outlets was designed using HY-8 and the Federal Highway Administration Hydraulic Engineering Circular No. 14: Hydraulic Design of Energy Dissipaters for Culverts and Channels.

We calculated the peak flow velocity in the culvert using HY-8. Tailwater velocity downstream of the outlet is calculated based on an assumed stream cross-section and peak flow.

We also used a risk framework to assess the risk of culvert blockage from debris flows and determine mitigation measures for inclusion in the Project. This risk framework is described in Section 4.1.8 below.

Locations

Culverts are typically provided in embankment sections where an existing watercourse intersects with the Project. The final location of the culverts will be determined at future stages of the Project and will be determined by the final road geometry for the Project.

The design of the culverts with respect to their locations has been carried out on the Indicative Alignment and we designed the horizontal and vertical alignments of the culverts to limit the environmental impact.

85 culverts have been designed for the Indicative Alignment which includes stream crossing and land drains. These are indicated in the Drawing Set: Stormwater Drawings (Volume 3 of the AEE) and the summary table contained in Appendix B provides the details for each culvert.

In general the culverts will likely be concrete pipes as they tend to be the most cost effective type of cross drainage, because concrete pipes are economical to produce and meet strength and durability requirements.

Fish passage

As noted previously in this report, for hydraulic design purposes we have assumed that all culverts will require some form of fish passage element to be incorporated into the design.

The particular requirements and fish passage type required at each culvert will be confirmed at future stages of the design in conjunction with the Project ecologist.

4.1.8 Debris hazard

We used a risk framework to assess the risk from debris to culvert blockage and determine mitigation measures for inclusion in the Project. Debris is carried by flood flows and by less frequent and more hazardous debris flows.

Debris flows are a fast flowing mixture of water with a medium or high proportion of solids, which moves down watercourses. Debris flows are triggered by heavy rainfall and can often occur in conjunction with landslides within the catchment. Debris flows are potentially destructive and can encompass a wide range of objects, such as fallen trees, stumps, boulders, gravels and soils, plus water.

Debris can accumulate at a culvert inlet or become lodged in the inlet or barrel. When this debris accumulation happens, the culvert will fail to perform as designed. Upstream flooding may occur and there may be a risk of roadway overtopping. This overtopping may put the motorway embankments at risk and their subsequent failure puts downstream environments, infrastructure and people at risk.

We developed a Debris Management Framework for the concept design of the Project. The Framework will be updated at the detailed design stage. At detailed design the debris flow potential in the catchments will be more closely examined considering geology and slope characteristics of catchments.

It will also be necessary to consider the potential for overtopping of the motorway embankment. Where there is a high consequence of culvert blockage, the potential impact category may need to be considered in accordance with the New Zealand Society on Large Dams (NZSOLD) guidelines, which may require higher design standards to be adopted for detailed design.

Risk

The risk associated with debris flow occurrence is a product of the likelihood of debris flows and the consequence of culvert blockage, this relationship is described below

We categorise the likelihood of debris flow occurrence as follows:

- **Low Likelihood** – Culverts where there is a low likelihood of debris in the upstream catchment are generally servicing small catchment areas where land-use is predominantly farmland or pasture. Farmland and pasture are unlikely to produce significant volumes of debris with culvert blocking potential during a storm event, particularly if the catchment is small.

- **Moderate Likelihood** – Culverts where there is a moderate likelihood of debris in the upstream catchment are generally servicing moderate sized catchment areas where the land-use is predominately bush or forestry. Bushland and forestry (both planted and clear-fell state) may produce tree and foliage debris in the event of a storm, generating landslides and resulting debris flows. A moderate sized catchment may create sufficient flow to transport debris material.

- **High Likelihood** – Culverts where there is a high likelihood of debris flow in the upstream catchment are generally servicing large catchment areas that include extensive bush and/or forestry. Bushland and forestry (both planted and clear-fell state) are likely to produce tree and foliage debris in the event of a storm, generating landslides and resulting debris flows. A large sized catchment is most likely to create sufficient flow to transport debris material.

The consequence associated with a blocked culvert is related to the potential flooding impact on the upstream side of the motorway and the risk to downstream areas from failure of road embankments. We have used the classification of a dam in the NZSOLD guidelines to categorise the consequence as low or high as shown as follows:

- **Low Consequence** – When blockage of a culvert occurs, a low consequence is either no effect or no inundation of buildings. In terms of the risk to the embankment, the volume of water stored behind the embankment is < 20,000 m^3 and less than 3 m in depth.

- **High Consequence** – When blockage of a culvert occurs, a high consequence is inundation of one or more buildings, flooding of the motorway, motorway embankment failure, and/or potential for loss of life. The volume of water stored behind the embankment is likely to be > 20,000 m^3 and more than 3 m in water depth.

Debris control measures

Where the risk of blockage of a culvert by debris is moderate or high, this risk needs to be mitigated by incorporating debris control measures into the design. The risk matrix for debris flow is also included in Table 5.

Table 5 – Risk matrix for debris flow

		Likelihood of debris flows and culvert blockage		
	RISK	Low	Moderate	High
Consequence of culvert blockage	Low	Low	Moderate	Moderate
	High	Low	Moderate	High

The following describes the mitigation measures we propose for the Project for different degrees of risk of blockage of a culvert by debris flow.

(a) **High risk**:

For culverts with a high risk of debris blockage, our preferred mitigation measure is to construct a debris control structure. This structure comprises a steel rack at least 20m upstream of the culvert and is designed to trap a proportion of large debris before it reaches the culvert. A typical detail of a debris rack is shown in the Drawing Set: Stormwater Drawings (Volume 3 of the AEE).

The debris rack will allow flow to overtop the trapped debris to maintain conveyance of flow through to the culvert. During operation of the motorway, ongoing inspections will be required to inspect debris screens and to undertake maintenance as required.

Further mitigation is provided by sizing the culvert with additional capacity to accommodate 100 year ARI flow with the top water level not exceeding the culvert soffit level (the highest point on the inside of the culvert). The additional sizing of the culvert to accommodate the 100 year ARI flow provides a generous culvert cross-sectional area that also reduces the potential risk of blockage due to debris.

(b) **Moderate risk**:

For culverts with a moderate risk of blockage due to debris accumulation, our preferred mitigation measure is to install a relief inlet, as shown in the Drawing Set: Stormwater Drawings (Volume 3 of the AEE).

A relief riser is a secondary intake with debris screen that is mounted on a vertical manhole over the culvert. In the event of any blockage of the culvert inlet the water will rise up the embankment to the relief inlet. The relief inlet allows flow to enter the culvert by this secondary inlet, and reduces flooding depths at the culvert.

The relief inlet has some resilience to blockage as rising water levels cause debris to float off the debris screen.

(c) **Low risk**:

For culverts within the Project that are at low risk of blockage due to debris accumulation, we do not consider any mitigation measures are necessary.

4.1.9 Erosion control at outlets

Wetland outfalls and culvert outlets will incorporate energy dissipation structures and/or erosion protection measures to minimise stream bed scour and bank erosion in the receiving waterway. Typically this protection from erosion will be through an energy dissipation device and/or rock aprons.

We consider these solutions standard practice and a matter to be addressed in the detailed design phase.

Energy dissipation

Energy dissipation structures are used to reduce high velocity and energy at the outlet of culverts prior to discharge back into the natural stream. Energy dissipation structures include stilling basins, impact basins and a range of other US Army Corps of Engineers (USACE) and Federal Highway Administration Hydraulic Engineering Circular No. 14 Hydraulic Design of Energy Dissipaters for Culverts and Channels (HEC-14) structures to suit different applications.

Energy dissipation structures have not been designed at this stage of the Project as it is not considered to be material to the consent applications to determine the designation footprint.

The flow chart for selection of energy dissipation based on the need for fish passage is shown in Figure 12. The design of energy dissipation structures will be developed during future stages of the design of the Project and the options to be considered for energy dissipation and erosion control for culvert outlets are outlined below. Other options may also be viable.

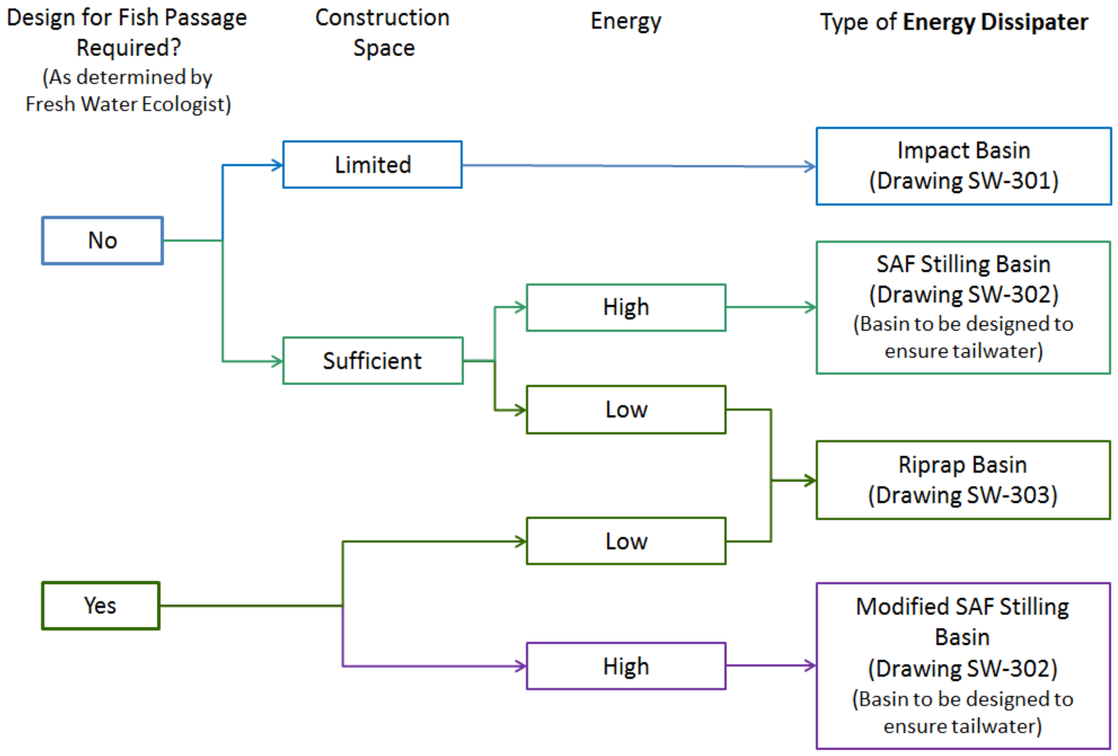

Figure 12 – Flow chart for energy dissipation

Impact basin

An impact basin is a box structure at the culvert outlet that dissipates energy by directing the flow onto a vertical baffle. It has the advantages of only requiring a small area for construction, can be constructed off site, and is applicable to a range of flows.

A typical detail for an impact basin is shown on Drawing SW-301. An example of an impact basin is shown in Photo 1 for the Otanerua wetland outfall on Northern Gateway Toll Road (NGTR).

An impact basin is not suitable for fish passage.

Impact basins are also not suitable where there is potential for debris load, as they are susceptible to blockage and it is extremely difficult to remove any blocked material. Impact basins are not proposed for any culverts but may be used for stormwater outfalls.

Photo 1 - Impact basin on NGTR Otanerua Wetland outfall

Riprap basin

A riprap basin is a rock lined basin containing a water pool at the culvert outlet to dissipate energy from the discharged flow.

The basin includes a rock apron downstream of the pool at a zero grade for a length related to the culvert diameter. The rock apron spreads the flow to further reduce the velocity and helping to transition flow to the natural waterway downstream.

Riprap basins are suitable for fish passage provided the detailing is correctly designed and constructed (e.g. fish passage into culvert outlet).

Riprap basins require a large area. A typical detail for a riprap basin is shown on Drawing SW-303. Until confirmation is received from the Project ecologists regarding the requirement for fish passage at culvert locations riprap basins, for the purposes of the design riprap basins have been assumed to be required at all culvert outlets.

An example of a riprap basin is shown in Photo 2 for the NGTR Nukumea culverts on NGTR. At this location concrete baffles are also used on the wingwall apron. The rock that forms the riprap basin is obscured by vegetation that has established around the pool. The presence of the vegetation confirms the effectiveness of the riprap pool for energy dissipation prior to discharge to the downstream environment. The pool also assists with fish passage into the culverts.

Photo 2 - Riprap basin for NGTR Nukumea culverts.

5 RECOMMENDATIONS AND CONCLUSIONS

The operational water design for the Indicative Alignment meets the various criteria required by the Auckland Council and NZ Transport Agency design standards and the AUP(OP). We have used a Best Practical Option Approach (BPO). However, we recognise that the design will be further refined at future design stages of the Project.

The operational water design will provide for design flows required in the stormwater collection and conveyance systems and the stormwater treatment systems will, through the design of devices in accordance with GD01, provide effective treatment of stormwater runoff and will remove Total Suspended Solids and other contaminants from the road runoff. A summary of the outcomes required to be met with respect to design criteria at future stages of the design is provided below.

5.1 Water quality

- Water quality treatment should be achieved through the design and construction of stormwater treatment devices, designed in accordance with GD01. This will remove suspended solids and contaminants of concern including Zinc, Copper and other persistent and bio-accumulative contaminants;

- Stormwater treatment devices should incorporate sediment forebays that will include submerged or baffled low flows outlets so that floatables and litter can be retained within the device;

- The stormwater collection, conveyance and treatment systems should incorporate a minimum 20 cubic metre volume that can be isolated in the event of a spillage on the road. The isolation valve will be able to be operated to prevent spillages from entering the receiving environment;

- Sediment traps should be incorporated within rock cuts drains to reduce the amount of sediment reaching the constructed wetlands during the operational phase of the Project;

- Vegetated roadside swales / drains should be provided for the treatment of stormwater runoff from local roads.

5.2 Water quantity

- The stormwater collection and conveyance system should be designed to cater for a 10 year ARI rainfall event in accordance with NZTA P46;

- Open channels and overland flow paths (stream diversions, cut-off drains) should be designed to cater for the 100 year ARI rainfall event;

- Culverts should be designed in accordance with NZTA P46. The inclusion of fish passage measures should be considered during the hydraulic design of the culverts. The specific fish passage measures depends on the fish species present in each of the streams and watercourses, which will be confirmed by the Project ecologist at future design stages of the Project;

- Erosion control measures should be provided at all culvert outlets and stormwater outfalls to open channel drains to prevent erosion of the downstream system;

- Stormwater treatment devices should incorporate a volume of stormwater storage to meet the Hydrology Mitigation requirement of the AUP(OP);

- Stormwater treatment devices should incorporate an emergency overflow or bypass systems that that will cater for the 100 year ARI flow from the upstream catchment.

APPENDIX A: WETLAND DESIGN – SUMMARY TABLE

Catchment	Wetland Reference	Catchment Areas (ha)					Wetland Sizing			Water Quality (Y/N)	Hydrology mitigation SMAF 1 (Y/N)	100 year ARI peak flow control (Y/N)	Outlet erosion protection (Y/N)
		Pervious	Cutface	Road	Total	Impervious Percentage (%)	Total Volume[1] (m^3)	Approx. Width[2] (m)	Approx. Length[3] (m)				
For Indicative Alignment preceding from north to south													
Oruawharo	Wetland CH24100 East	0.4	0.0	1.1	1.5	75%	1,488	30	81	Y	Y	N	Y
Oruawharo	Wetland CH24480 East	0.8	0.0	5.4	6.2	87%	7,317	58	165	Y	Y	N	Y
Oruawharo	Wetland MCM0 CH2140	0.0	0.3	1.5	1.9	100%	2,115	34	91	Y	Y	N	Y
Oruawharo	Wetland CH25840 West	1.5	0.0	2.6	4.2	64%	3,781	45	126	Y	Y	N	Y
Oruawharo	Wetland CH26000 East	1.8	0.0	3.6	5.4	67%	5,066	52	145	Y	Y	N	Y
Oruawharo	Wetland CH26360 East	1.4	1.2	2.5	5.1	72%	3,388	42	115	Y	Y	N	Y
Oruawharo	Wetland CH27960 East	0.5	0.0	3.1	3.6	85%	4,379	47	132	Y	Y	N	Y
Oruawharo	Wetland CH27960 West	2.0	0.0	3.1	5.2	60%	3,779	45	125	Y	Y	N	Y
Oruawharo	Wetland CH28980 West	0.0	0.1	2.4	2.5	100%	3,315	41	112	Y	Y	N	Y
Oruawharo	Wetland CH29860 East	0.0	2.0	1.8	3.8	100%	2,523	35	95	Y	Y	N	Y
Hōteo	Wetland CH30960 East	0.0	1.5	1.7	3.2	100%	2,425	35	95	Y	Y	N	Y
Hōteo	Wetland CH31620 East	2.9	1.0	1.7	5.5	48%	2,387	35	95	Y	Y	N	Y
Hōteo	Wetland CH32660 East	3.4	1.8	3.4	8.7	60%	4,900	48	134	Y	Y	N	Y
Hōteo	Wetland CH33940 East	11.2	0.0	3.8	15.1	25%	5,465	50	141	Y	Y	N	Y
Hōteo	Wetland CH34320 West	2.5	0.0	3.1	5.6	55%	4,212	47	130	Y	Y	N	Y
Hōteo	Wetland CH35550 West	4.3	0.0	3.4	7.6	44%	4,908	49	136	Y	Y	N	Y
Hōteo	Wetland CH36920 East	6.5	0.0	5.2	11.7	44%	7,951	61	173	Y	Y	N	Y
Hōteo	Wetland CH37580 West	2.6	1.7	6.3	10.6	76%	10,137	67	192	Y	Y	N	Y

Catchment	Wetland Reference	Catchment Areas (ha)					Wetland Sizing			Water Quality (Y/N)	Hydrology mitigation SMAF 1 (Y/N)	100 year ARI peak flow control (Y/N)	Outlet erosion protection (Y/N)
		Pervious	Cutface	Road	Total	Impervious Percentage (%)	Total Volume[1] (m^3)	Approx. Width[2] (m)	Approx. Length[3] (m)				
	Wetland CH38460 East	0.0	1.2	1.6	2.7	100%	2,578	34	93	Y	Y	N	Y
	Wetland CH38880 North	0.0	6.4	1.9	8.3	100%	3,963	40	111	Y	Y	N	Y
	Wetland CH39460 North	0.0	2.2	1.1	3.4	100%	2,164	31	84	Y	Y	N	Y
	Wetland CH39900 North	0.0	2.9	1.5	4.5	100%	2,927	35	94	Y	Y	N	Y
	Wetland CH40300 North	0.0	5.2	1.6	6.8	100%	3,366	38	103	Y	Y	N	Y
	Wetland CH40850 South	0.0	3.9	2.9	6.8	100%	5,568	46	128	Y	Y	N	Y
	Wetland CH42350 North	0.0	3.4	2.1	5.6	100%	4,201	40	110	Y	Y	N	Y
	Wetland CH43150 North	0.0	4.7	2.7	7.5	100%	5,470	44	123	Y	Y	N	Y
	Wetland CH43300 North	0.0	2.6	2.9	5.5	100%	5,512	47	131	Y	Y	N	Y
	Wetland CH43800 South	0.0	5.7	2.1	7.8	100%	4,482	42	116	Y	Y	N	Y
	Wetland CH46500 West	0.0	5.7	3.8	9.5	100%	7,391	51	144	Y	Y	N	Y
	Wetland CH47300 West	0.0	0.0	3.1	3.1	100%	5,154	48	133	Y	Y	N	Y
Mahurangi	Wetland CH48220 West	0.0	4.1	4.7	8.7	100%	8,129	55	155	Y	Y	N	Y
	Wetland MC30 CH1845	0.0	0.9	2.7	3.6	100%	4,465	48	135	Y	Y	N	Y
	Wetland CH48940 West	0.0	0.3	4.5	4.8	100%	7,419	56	157	Y	Y	N	Y
	Wetland CH49380 West	0.0	0.0	2.1	2.1	100%	3,498	44	122	Y	Y	N	Y
	Totals	**42.0**	**58.9**	**97.2**	**198.2**	**79%**							

Notes:
1 –catering up to 10 year peak flow control
2 –Including allowance for freeboard and maintenance access
3 –Including allowance for freeboard and maintenance access

APPENDIX B: CULVERT DESIGN – SUMMARY TABLE

Catchment	Culvert Reference	Cross sectional type	Diameter / Height (mm)	Width (mm)	No. Barrels	Length[1] (m)	Fish Passage[2] (Y/N)	Debris Management[3] (Y/N)	Energy dissipation structure (Y/N)	Stream diversion type
For Indicative Alignment preceding from north to south										
Oruawharo	CULVERT 24000[4]	Circular	2300	–	3	74	Y	Y	Y	Lowland
	CULVERT 24860	Circular	1200	–	1	75	Y	N	Y	Lowland
	CULVERT 24940 SH1[4]	Circular	3050	–	3	27	Y	Y	Y	Lowland
	CULVERT 24980	Circular	2100	–	1	135	Y	Y	Y	Lowland
	CULVERT 25400	Circular	1350	–	1	84	Y	N	Y	Lowland
	CULVERT 25710	Box	1500	1500	1	85	Y	N	Y	Lowland
	CULVERT 26090	Circular	2550	–	1	165	Y	Y	Y	Lowland
	CULVERT 27090	Circular	1500	–	1	79	Y	N	Y	Highland
	CULVERT 27740	Box	3000	3000	2	156	Y	Y	Y	Lowland
	CULVERT 27900	Circular	2100	–	1	102	Y	Y	Y	Lowland
	CULVERT 28380	Circular	2100	–	1	66	Y	Y	Y	Lowland
	CULVERT 28780 RD[4]	Box	1500	4000	3	5	Y	Y	Y	Lowland
	CULVERT 28850	Box	2000	3000	2	71	Y	Y	Y	Lowland
	CULVERT 28930	Circular	2550	–	1	95	Y	Y	Y	Lowland
	CULVERT 29190	Circular	2100	–	1	87	Y	Y	Y	Lowland
	CULVERT 29380	Circular	2100	–	1	105	Y	Y	Y	Lowland
Hōteo	CULVERT 32530	Circular	2550	–	3	149	Y	Y	Y	Lowland

Catchment	Culvert Reference	Cross sectional type	Diameter / Height (mm)	Width (mm)	No. Barrels	Length[1] (m)	Fish Passage[2] (Y/N)	Debris Management[3] (Y/N)	Energy dissipation structure (Y/N)	Stream diversion type
	CULVERT 32600	Circular	2100	–	3	167	Y	Y	Y	Lowland
	CULVERT 33530	Box	1500	2500	1	46	Y	Y	Y	Highland
	CULVERT 34190	Circular	3050	–	2	83	Y	Y	Y	Lowland
	CULVERT 34520	Circular	2300	–	1	81	Y	Y	Y	Lowland
	CULVERT 35380	Box	4000	4000	3	72	Y	Y	Y	Lowland
	CULVERT 35910	Circular	1200	–	3	45	Y	N	Y	Lowland
	CULVERT 36180	Circular	2100	–	1	52	Y	Y	Y	Lowland
	CULVERT 36650	Circular	3050	–	2	108	Y	Y	Y	Lowland
	CULVERT 37320 RD[4]	Circular	1050	–	2	19	Y	N	Y	Lowland
	CULVERT 37630	Circular	3050	–	2	91	Y	Y	Y	Lowland
	CULVERT 39200 SH1[4]	Circular	1050	–	2	31	Y	N	Y	Lowland
	CULVERT 39300 SH1[4]	Circular	2100	–	3	30	Y	Y	Y	Lowland
	CULVERT 39400	Circular	2300	–	1	151	Y	Y	Y	Highland
	CULVERT 39500 SH1[4]	Circular	2300	–	3	33	Y	Y	Y	Lowland
	CULVERT 39750	Circular	2100	–	1	170	Y	Y	Y	Highland
	CULVERT 39900 SH1[4]	Circular	1200	–	3	32	Y	Y	Y	Lowland
	CULVERT 40200	Circular	3050	–	1	200	Y	Y	Y	Highland
	CULVERT CH40300 SH1[4]	Circular	2100	–	3	36	Y	Y	Y	Lowland
	CULVERT 40950	Circular	2550	–	2	298	Y	Y	Y	Highland
	CULVERT 41250	Circular	2300	–	1	110	Y	Y	Y	Highland
	CULVERT 41750	Circular	2100	–	1	295	Y	Y	Y	Highland
	CULVERT 41850	Circular	2550	–	1	328	Y	Y	Y	Highland

Catchment	Culvert Reference	Cross sectional type	Diameter / Height (mm)	Width (mm)	No. Barrels	Length[1] (m)	Fish Passage[2] (Y/N)	Debris Management[3] (Y/N)	Energy dissipation structure (Y/N)	Stream diversion type
	CULVERT 42540	Circular	2100	–	1	208	Y	Y	Y	Highland
	CULVERT 42750	Circular	2300	–	1	192	Y	Y	Y	Highland
	CULVERT 43250	Circular	2550	–	1	143	Y	Y	Y	Highland
	CULVERT 43300	Circular	2100	–	1	184	Y	Y	Y	Highland
	CULVERT 43700	Circular	2550	–	1	202	Y	Y	Y	Highland
	CULVERT 44300	Circular	1500	–	1	62	Y	N	Y	Highland
	CULVERT 45650	Circular	2550	–	1	140	Y	Y	Y	Highland
	CULVERT 46150	Circular	2100	–	1	135	Y	Y	Y	Highland
	CULVERT 47200	Circular	2300	–	1	63	Y	Y	Y	Lowland
	CULVERT 47850	Circular	2100	–	1	129	Y	Y	Y	Lowland
	CULVERT 48400	Circular	2300	–	1	90	Y	Y	Y	Lowland
	CULVERT 48700	Circular	1650	–	1	97	Y	N	Y	Lowland
	CULVERT 49500[4]	Box	3500	2500	3	121	Y	Y	Y	Lowland
Mahurangi	CULVERT MC10 1100	Box	1000	2500	3	27	Y	Y	Y	Lowland
	CULVERT MC10 1660	Box	500	3000	2	26	Y	N	Y	Lowland
	CULVERT MC10 1800	Box	1000	3000	2	23	Y	Y	Y	Lowland
	CULVERT MC10 2180	Box	1000	3000	3	18	Y	Y	Y	Lowland
	CULVERT MC10 2350	Box	1000	3000	2	32	Y	Y	Y	Lowland
	CULVERT MC30 400	Circular	1950	–	1	45	Y	N	Y	Lowland
Oruawharo	CULVERT MCB0 350	Circular	1050	–	1	14	Y	N	Y	Lowland
Hōteo	CULVERT MCC0 770[4]	Box	2000	3000	1	48	Y	Y	Y	Lowland
	CULVERT MCE0 230	Box	500	3000	3	21	Y	Y	Y	Lowland

Catchment	Culvert Reference	Cross sectional type	Diameter / Height (mm)	Width (mm)	No. Barrels	Length[1] (m)	Fish Passage[2] (Y/N)	Debris Management[3] (Y/N)	Energy dissipation structure (Y/N)	Stream diversion type
	CULVERT MCF0 670[4]	Circular	2050	–	2	29	Y	Y	Y	Lowland
Mahurangi	CULVERT MCG0 280	Circular	1500	–	1	72	Y	N	Y	Lowland
Hōteo	CULVERT MCG0 820	Circular	2100	–	1	18	Y	Y	Y	Lowland
	CULVERT MCG1 280	Box	3500	3000	3	27	Y	Y	Y	Lowland
	CULVERT MCH0 20	Circular	1800	–	2	41	Y	Y	Y	Lowland
	CULVERT MCH0 190	Circular	1350	–	2	38	Y	N	Y	Lowland
	CULVERT MCH0 700	Box	1500	3000	2	19	Y	Y	Y	Lowland
Oruawharo	CULVERT MCM0 1420	Box	1000	3000	1	25	Y	N	Y	Lowland
	CULVERT MCM0 1710	Circular	3050	–	2	82	Y	Y	Y	Lowland
	CULVERT MCM0 1930	Circular	1500	–	1	46	Y	N	Y	Lowland
Mahurangi	CULVERT MCO0 40	Box	1500	3000	2	22	Y	Y	Y	Lowland
Hōteo	CULVERT MCO0 520	Circular	1050	–	3	60	Y	N	Y	Lowland
	CULVERT MCO0 840	Circular	1050	–	1	32	Y	N	Y	Lowland
Oruawharo	CULVERT MCQ0 1000[4]	Box	2000	3000	3	31	Y	Y	Y	Lowland
Hōteo	CULVERT MCR0 80[4]	Box	3500	3000	3	28	Y	Y	Y	Lowland
	CULVERT MCR0 480	Circular	600	–	1	32	Y	N	Y	Highland
Oruawharo	CULVERT MCV0 20	Circular	525	–	1	25	Y	N	Y	Lowland
	CULVERT MCV0 710	Box	500	3000	2	20	Y	N	Y	Lowland
	CULVERT MCV0 870	Box	1000	3000	1	33	Y	N	Y	Lowland
	CULVERT MCV0 1160	Box	1000	2500	1	16	Y	N	Y	Lowland
Hōteo	CULVERT MCW0 1070[4]	Circular	2100	–	1	12	Y	Y	Y	Lowland
	CULVERT MCW0 1360[4]	Circular	1050	–	3	18	Y	N	Y	Lowland

Catchment	Culvert Reference	Cross sectional type	Diameter / Height (mm)	Width (mm)	No. Barrels	Length[1] (m)	Fish Passage[2] (Y/N)	Debris Management[3] (Y/N)	Energy dissipation structure (Y/N)	Stream diversion type
Mahurangi	CULVERT MCY0 100	Box	500	2000	2	21	Y	Y	Y	Lowland
	CULVERT MCY0 200	Box	1500	2000	3	28	Y	Y	Y	Lowland

Notes:
1 – Lengths are measured in plan (horizontally) actual lengths will differ and are longer due to slope.
2 – Assumed all require fish passage until further investigation in detailed design.
3 – Debris management includes: Debris rack and culvert sized to pass 100 year ARI without surcharge/relief inlet.
4 – Identified existing culverts which may require upgrading/extending/realigning – to be confirmed by in depth investigation and analysis.