Roads of national significance

Ara Tūhono – Pūhoi to Wellsford

Pūhoi to Warkworth

Operational Water Assessment Report

August 2013

Pūhoi to Warkworth

Document title: **Operational Water Assessment Report**

Version: Final

Date: 20 August 2013

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File name: 500-037 Operational Water Assessment Report_Final_20 August 2013

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Glossary of abbreviations

Abbreviation	Definition
AEE	Assessment of Environmental Effects
AMA	Auckland Motorway Alliance
ANZECC	Australian and New Zealand Environment Conservation Council
ARC	Auckland Regional Council (preceded the Auckland Council)
ARI	Average Recurrence Interval
ARP: ALW	Auckland Regional Plan: Air, land and water
ARP: C	Auckland Regional Plan: Coastal
BPO	Best Practicable Option
Ch	Chainage
CMA	Coastal Marine Area
CN	Soil Conservation Service Curve Number
Cu	Copper
DO	Dissolved Oxygen
ha	Hectares
HEC-14	Federal Highway Administration Hydraulic Engineering Circular No. 14 Hydraulic Design of Energy Dissipaters for Culverts and Channels
HIRDS	High Intensity Rainfall Design System
HY-8	Federal Highway Administration Culvert Design Software, USA
ICM	InfoWorks Integrated Catchment Modelling Software
LiDAR	Light Detection and Ranging
m	Metres
MfE	Ministry for the Environment
MHG	Mahurangi Hydrograph
MHWS	Mean High Water Springs
MSE	Mechanically Stabilised Earth
NGTR	Northern Gateway Toll Road
NIWA	National Institute of Water and Atmosphere

Abbreviation	Definition
NZSOLD	New Zealand Society on Large Dams
NZTA	NZ Transport Agency
PHG	Pūhoi Hydrograph
RDC	Rodney District Council (preceded Auckland Council)
RL	Reduced Level
RMA	Resource Management Act 1991
RoNS	Roads of National Significance
SAF	Saint Anthony Falls (Stilling Basin)
SHx	State Highway (number)
XP-SWMM	XP Solution Storm Water Management Model (software)
TPH	Total Petroleum Hydrocarbon
TP10	ARC Technical Publication Number 10: Stormwater Management Devices Design Guideline Manual
TP108	ARC Technical Publication 108: Guidelines for Stormwater Runoff Modelling in the Auckland Region
TSS	Total Suspended Solids
Zn	Zinc

Glossary of defined terms

Term	Definition
Afflux	Rise in water level on the upstream side of a bridge or culvert.
Alignment	The route or position of a proposed motorway or state highway.
Allochthon	A large block of rock which has been moved from its original site of formation, usually by low angle thrust faulting.(colloquially known as "Onerahi chaos")
Average Recurrence Interval	The average time period between rainfall or flow events that equal or exceeds a given magnitude. Similar to return period.
Bathymetry	The measurement of the depths of bodies of water.
Bore	Any hole that has been constructed to provide access to groundwater (for example, for monitoring of ground or groundwater conditions, taking of groundwater or the discharge of stormwater).
Culvert	A pipe with an inlet from a watercourse and outlet to a watercourse, designed to convey water under a specific structure (such as a road).
Degradation	A general and progressive (long-term) lowering of a stream channel bed due to erosion, over a relatively long channel length.
Diversion of stormwater	The turning aside of stormwater from its natural course of flow; causing it to flow by a different route.
Earthworks	The disturbance of land surfaces by blading, contouring, ripping, moving, removing, placing or replacing soil or earth, or by excavation, or by cutting or filling operations.
Erosion Control	Methods to prevent or minimise the erosion of soil, in order to minimise the adverse effects that land disturbing activities may have on a receiving environment.
Fish Passage	The movement of fish between the sea and any river, including up-stream or downstream in that river.
Grassed Swales	Vegetated areas used in place of kerbs or paved gutters to transport stormwater runoff. They also can temporarily hold quantities of runoff and allow it to infiltrate into the soil.
Groundwater	Natural water contained within soil and rock formations below the surface of the ground.
Heading up	Heading up is the term used to denote the condition when the water surface immediately upstream of the culvert rises to an elevation greater than the soffit of the culvert inlet.
Headwater	The difference in elevation from the culvert invert at the inlet, to the water surface of the pool that forms as a result of heading up, is called the headwater.
Indicative Alignment	A route and designation footprint selected after short-list and long-list development to enable consultation with the community. This development involved specialist work assessing environmental, social and engineering inputs.
Intermittent Stream	Any stream or part of a stream that is not a Permanent stream.
Mechanically Stabilised Earth Slope	Internally reinforced soil structures with face angles less than 70 degrees. Slope faces steeper than 70 degrees are termed mechanically stabilised earth (MSE) walls.

Term	Definition
Motorway	Motorway means a motorway declared as such by the Governor-General in Council under section 138 of the Public Works Act 1981or under section 71 of the Government Roading Powers Act 1989.
Overland Flow Path	The flow path of stormwater over the ground.
Permanent Stream	Downstream of the uppermost reach of a river or stream which meets either of the following criteria: (a) has continual flow; or (b) has natural pools having a depth at their deepest point of not less than 150 millimetres and a total pool surface area that is $10m^2$ or more per 100 metres of river or stream bed length. The boundary between Permanent and Intermittent river or stream reaches is the uppermost qualifying pool in the uppermost qualifying reach.
Pier	Vertical support structure for a bridge.
Portal	The entrance to a tunnel starting where the road is completely uncovered to where it is completely covered.
Project	Pūhoi to Warkworth section of the Pūhoi to Wellsford Road of National Significance Project
Project area	From the Johnstone's Hill tunnel portals in the south to Kaipara Flats Road in the north.
Reclamation	Defined in the Auckland Regional Plan: Coastal as any permanent filling of an area previously inundated by coastal water either at or above mean high water spring mark, whether or not it is contiguous with the land, so that the filled surface is raised above the natural level of MHWS, and thus creates dry land, removed from the ebb and flow of the tide.
Reduced Level	Equating levels / elevations to a common datum
Secondary flow path	The flow path of stormwater or floodwater that activates for larger storm events.
Sediment Control	Capturing sediment that has been eroded and entrained in overland flow before it enters the receiving environment.
Turbidity	Turbidity is a measure of water clarity or murkiness of a waterbody.
Wetland	Vegetated stormwater treatment device designed to remove a range of contaminants, providing superior water quality treatment to wet ponds with increased filtering and biological treatment performance.

Contents

Figures

Tables

1. Introduction

This report constitutes an assessment of the operational water effects of the Pūhoi to Warkworth Project (the Project), which is a section of the Ara Tūhono Pūhoi to Wellsford Road of National Significance (RoNS). Operational water effects are those arising from stormwater, streamworks and flooding associated with the operational phase of the Project. The report also describes the operational water systems, including the permanent stormwater management systems and modifications to streams/floodplains for the operation of the motorway. Construction effects are considered separately in the Construction Water Assessment Report.

We have minimised effects by designing mitigation measures into the Project's operational water systems based on a best practicable option approach. The extent of mitigation measures is based on consideration of the sensitivity of the receiving environment and our assessments of the potential unmitigated effects. The residual environmental effects are assessed in this report.

1.1 Purpose and scope of this report

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's Ara Tūhono Pūhoi to Wellsford Road of National Significance (RoNS) Pūhoi to Warkworth Section (the Project). Its purpose is to inform the Assessment of Environmental Effects (AEE) and to support the resource consent applications and Notices of Requirement for the Project. This report has been prepared by Tim Fisher and Michelle Sands, with the invaluable assistance of David Sloan, Christian Gamst, Simon Wang, Simonne Elliot, Wolfram Schluter and Ben Fountain.

This report constitutes an assessment of the operational water effects of the Project. Operational water effects are those arising from stormwater, streamworks and flooding associated with the operational phase of the Project. This report also describes the operational water systems, including the permanent stormwater management systems and modifications to streams/floodplains for the operation of the motorway. Construction effects are considered separately in the Construction Water Assessment Report.

The indicative alignment shown on the Project drawings has been developed through a series of multi-disciplinary specialist studies and refinement. A NZTA scheme assessment phase was completed in 2011, and further design changes have been adopted throughout the AEE process for the Project in response to a range of construction and environmental considerations.

It is anticipated that the final alignment for the Project will be refined and confirmed at the detailed design stage through conditions and outline plans of works. For that reason, this assessment has addressed the actual and potential effects arising from the indicative alignment, and covers the proposed designation boundary area.

Except as noted in this Report:

- We consider that the sites we have selected for surveys and testing are generally representative of all areas within the proposed designation boundary; and
- The recommendations we propose to mitigate adverse effects are likely to be applicable to other similar areas within the proposed designation boundary, subject to confirmation of their suitability at the detailed design stage.

1.2 Overview of operational water systems

Figure 1 provides a pictorial overview of how water is managed in the operational phase of the Project.

Rainfall onto cuts and the motorway is collected and conveyed via stormwater treatment devices prior to discharge to streams which then drain to the estuary and harbours. Rainfall onto adjacent areas is diverted away from cuts and the motorway. Meanwhile streams that cross the motorway alignment are crossed by culverts or bridges. Culverts often require stream diversions to facilitate their construction. In some circumstances (not shown in Figure 1) the motorway fills occupy floodplains.

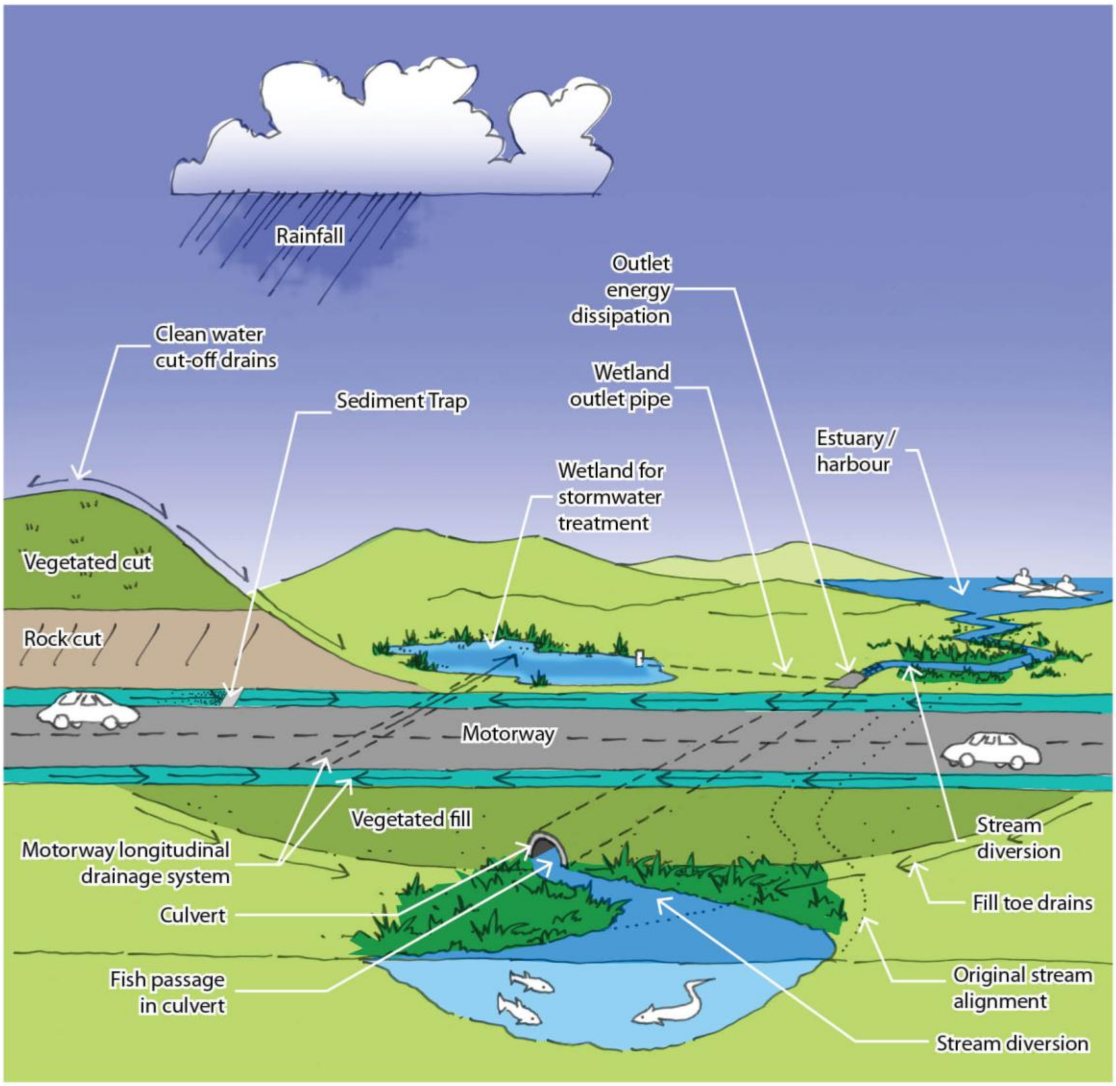

Figure 1: Motorway Operational Water Systems and the Environment

1.3 Overview of potential effects and our approach to mitigation

The following operational activities arising from the Project have the potential to create adverse effects on the environment:

- Stormwater from the road;
- Diversion and culverting of streams; and
- Flooding.

This section provides an overview of the potential adverse effects that may arise from these activities and our approach for selecting mitigation measures. This Report assesses the residual effects that remain after mitigation measures are employed.

The potential for water quality effects arises from stormwater runoff from roads, which carries pollutants from car exhausts, tyres and brakes and oils, which can adhere to sediment particles. The changes to the chemical make-up of stormwater and the receiving water, and accumulation of contaminants within that water may affect water quality, which can then have effects on the viability of aquatic ecosystems in streams, estuaries and harbours.

In addition, water quality will be influenced by the discharge of sediment and other eroded materials as a result of the Project. Deposition of sediments in streams can affect ecosystems beyond the Project area.

The potential water quantity (flow) effects are caused by an increase in impervious areas, reduction in infiltration to ground and diversion of stormwater into alternate drainage systems. These changes may increase the flow and volume of water discharging to streams and harbours. Changes in the hydrological cycle can also cause flooding, which can have direct effects on public safety and property. Hydrological changes can also cause stream erosion, and erosion and sedimentation can affect aquatic habitats.

In addition, water quantity may be affected by streamworks in the form of bridges, culverts and stream diversions, as well as by alterations to the floodplains within the Pūhoi and Mahurangi catchments. The changes to the streams have the potential to cause adverse effects on aquatic habitats. Modifications to the floodplain have the potential to affect flood water levels due to changes in flood storage and/or flow conveyance.

1.4 Our approach to mitigation and assessing the effects

1.4.1 Stormwater

We have assessed the stormwater effects of the Project on the environment based on the requirements of the following documents:

- Resource Management Act 1991 (RMA);
- Auckland Regional Plan: Air, Land and Water (ARP: ALW); and
- Other regional and district plans.

We have also considered the requirements of relevant current surface water users and consents.

The assessment criteria are based on these documents (refer Section 5) and form the basis for our assessment of effects (refer Section 8).

We describe the existing environment to provide a context for the assessment of effects (refer Section 4).

In particular, we have assessed the effects of stormwater using stormwater quality and hydrological methods and models (methodology described in Section 6). The ARP: ALW also requires treatment of stormwater to be achieved via the selection of the best practicable option (BPO) and stormwater design in accordance with the (former) Auckland Regional Council Technical Publication 10 (described in Section 7).

We have minimised effects by designing mitigation measures into the Project's operational water systems. These mitigation measures are based on a BPO approach and consideration of the sensitivity of pre-development environments. For example, extended detention is provided where the receiving streams are sensitive to stream erosion.

The consent design of the Project's stormwater systems for the indicative alignment is summarised in Water Assessment Factual Report 6: Stormwater Design Philosophy Report. The key design principles of that report are summarised in Section 6.1 of this Report.

The effects of stormwater on water quality and water quantity are assessed in Section 8, based on the residual effects after the proposed mitigation measures. The effects of stormwater on aquatic ecology are assessed in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

1.4.2 Streamworks

We derived the criteria for assessment for streamworks from the provisions of the RMA and Plans, including the ARP: ALW (refer Section 5). The effects of streamworks on water quality and quantity are assessed in Section 8 based on the residual effects with the proposed mitigation measures incorporated into the design. The ecological effects arising from streamworks are assessed in the Freshwater Ecology Assessment Report.

We have minimised effects by designing mitigation measures into the Project's streamworks based on a BPO approach and consideration of the sensitivity of pre-development environments. We have worked closely with the Project team's freshwater ecologists and have based our stream diversion design on their stream assessments.

The Project's approach to stream diversions is outlined in the stream diversion requirements, which are a set of integrated principles for stream hydraulics and ecological function. Stream diversion requirements are summarised in Section 7.9 and described in detail in Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo. The stream diversion requirements provide a basis for assessing environmental effects and recommending appropriate conditions for the subsequent design and construction phases of the Project. Our recommended conditions are summarised in Section 9 of this Report.

1.4.3 Flooding

The existing environment is described for each catchment to provide a context for the assessment of effects (refer Section 4). We developed criteria for our assessment of the flood effects based on the provisions of the RMA and Plans, including the ARP: ALW (refer Section 5).

Our approach to flooding has been to work cooperatively with Auckland Council and its modelling team, which is actively assessing the flood risk in the Warkworth area through flood management models to define hazards and to plan for mitigation options. This BPO approach is discussed in Section 7.10. We have assessed the effects of the Project on flooding using Auckland Council's rapid flood hazard model. The modelling methodology is described in Section 6 and results are documented in Section 8.

We have avoided adverse flooding effects where possible by the choice of alignment or mitigated thereafter by design measures. An example of this mitigation is the provision of bridges over the main floodplains and major secondary flow paths.

1.5 How to read this report

This Report is structured with summary boxes for each section, which collectively form an executive summary. The conclusions and recommendations (Section 9) summarise our key findings.

The structure of the Report is as follows:

Table 1: Report Structure

What	Where	Description
Introduction	Section 1	An introduction to the purpose and scope of this Report and its relationship to other assessment reports. This section introduces the potential effects of the Project from stormwater, streamworks and flooding. This section also describes the approach we have taken to minimise effects by mitigation measures and then assess the residual effects.
Project Description	Section 2	The description for the Project noting that a more detailed summary of the stormwater and streamworks aspects of the Project is provided in Section 3.
	Section 3	A description of the operational water systems we have developed.
Existing Environment	Section 4	A description of the existing environment relevant to the design and assessment of effects.
Assessment Matters	Section 5	A summary of the assessment matters that are the focus of this Report. These matters form the basis of the assessment criteria in Section 8.
Assessment Methodology	Section 6	Summary of our design and assessment methodology.
BPO	Section 7	A summary of the BPOs approach we have adopted and worked through to establish measures and controls to mitigate effects on the environment by operational water management.

What	Where	Description
Assessment	Section 8	An assessment of any residual effects of the operational water management systems we propose.
Conclusions and Recommendations	Section 9	Our conclusions and recommendations.

The Report should be read in conjunction with the 'SW' Drawing series.

A number of individual technical reports form the overall AEE for the Project. Where necessary, we reference the relevant reports directly in this report as follows:

- Construction Water Assessment Report
- Construction Section of the AEE Methodology
- Cultural Assessment Report
- Freshwater Ecology Assessment Report
- Marine Ecology Assessment Report
- Terrestrial Ecology Assessment Report
- Construction Traffic Assessment Report
- Transportation and Traffic Assessment Report

The Geotechnical Appraisal Report is referred in in this report however it does not form part of the application documentation for the Project.

We also produced a number of Water Assessment Factual Reports to supplement and inform the preparation of this Operational Water Assessment Report. These Water Assessment Factual Reports contain detailed calculations, design details and supporting information. These factual reports do not form part of the application documentation for the Project.

The Water Assessment Factual Reports that are relevant to this Report are as follows:

- Water Assessment Factual Report 4: Water Quality Monitoring Report
- Water Assessment Factual Report 5: Coastal Processes Modelling Report.
- Water Assessment Factual Report 6: Stormwater Design Philosophy Report
- Water Assessment Factual Report 7: Hydrological Data Memo
- Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo
- Water Assessment Factual Report 9: Hydrological Assessment Memo
- Water Assessment Factual Report 10: Flood Assessment Memo
- Water Assessment Factual Report 11: Motorway Runoff Report

Figure 2 describes the interaction between some of the Project Assessment Reports and the background Water Assessment Factual Reports.

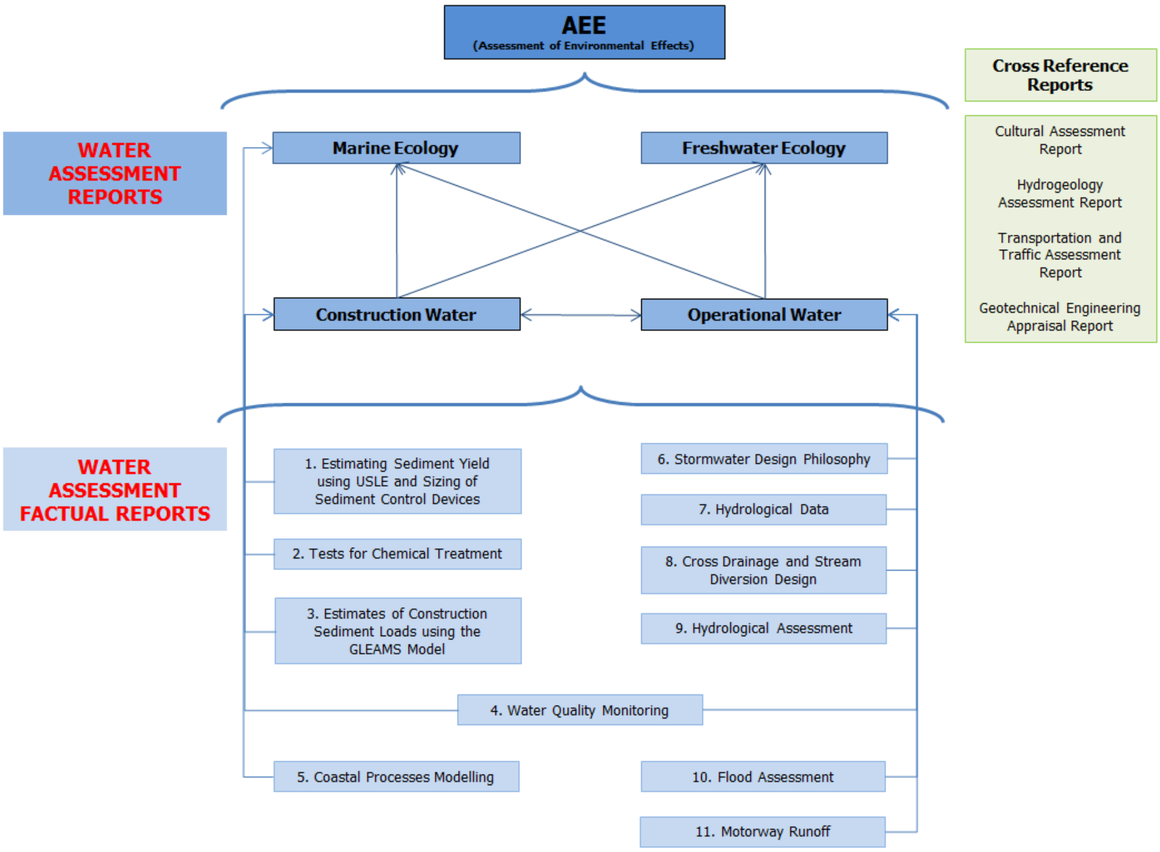

Figure 2: Operational Water Assessment Report – Relationship to other reports

2. Project description

The Project realigns the existing State Highway 1 (SH1) from the Northern Gateway Toll Road (NGTR) at the Johnstone's Hill tunnels and joins back in to the existing SH1 just north of Warkworth. The alignment will bypass Warkworth on the western side and tie into the existing SH1 north of Warkworth. It will be a total of 18.5km in length. The upgrade will be a new four-lane dual carriageway road, designed and constructed to motorway standards and the NZTA RoNS standards.

This Project description provides the context for this assessment. Sections 5 and 6 of the Assessment of Environment Effects (Volume 2) further describe the construction and operational aspects of the Project and should be relied upon as a full description of the Project.

The Project realigns the existing SH1 between the Northern Gateway Toll Road (NGTR) at the Johnstone's Hill tunnels and just north of Warkworth. The alignment will bypass Warkworth on the western side and tie into the existing SH1 north of Warkworth. It will be a total of 18.5km in length. The upgrade will be a new four-lane dual carriageway road, designed and constructed to motorway standards and the NZTA RoNS standards.

2.1 Project features

Subject to further refinements at the detailed design stage, key features of the Project are:

- A four-lane dual carriageway (two lanes in each direction with a median and barrier dividing oncoming lanes);
- A connection with the existing NGTR at the Project's southern extent;
- A half diamond interchange providing a northbound off-ramp at Pūhoi Road and a southbound on-ramp from existing SH1 just south of Pūhoi;
- A western bypass of Warkworth;
- A roundabout at the Project's northern extent, just south of Kaipara Flats Road to tie-in to the existing SH1 north of Warkworth and provide connections north to Wellsford and Whangarei;
- Construction of seven large viaducts, five bridges (largely underpasses or overpasses and one flood bridge), and 40 culverts in two drainage catchments: the Pūhoi River catchment and the Mahurangi River catchment;
- Construction of 3075m of stream diversions with natural stream forms;
- Construction of 27 wetlands; and
- A predicted volume of earthworks being approximately 8M m3 cut and 6.2M m3 fill within a proposed designation area of approximately 189 ha earthworks.

The existing single northbound lane from Waiwera Viaduct and through the tunnel at Johnstone's Hill will be remarked to be two lanes. This design fully realises the design potential of the Johnstone's Hill tunnels.

The current southbound tie-in from the existing SH1 to the Hibiscus Coast Highway will be remarked to provide two way traffic (northbound and southbound), maintaining an alternative route to the NGTR. The existing northbound tie-in will be closed to public traffic as it will no longer be necessary.

The current southbound tie-in from the existing SH1 to the Hibiscus Coast Highway will be remarked to provide two way traffic (northbound and southbound), maintaining an alternative route to the NGTR. The existing northbound tie-in will be closed to public traffic as it will no longer be necessary.

2.2 Route description by Sector

For assessment and communication purposes, the Project has been split into six sectors, as shown in Figure 3. Section 5.3 of the AEE describes these sectors.

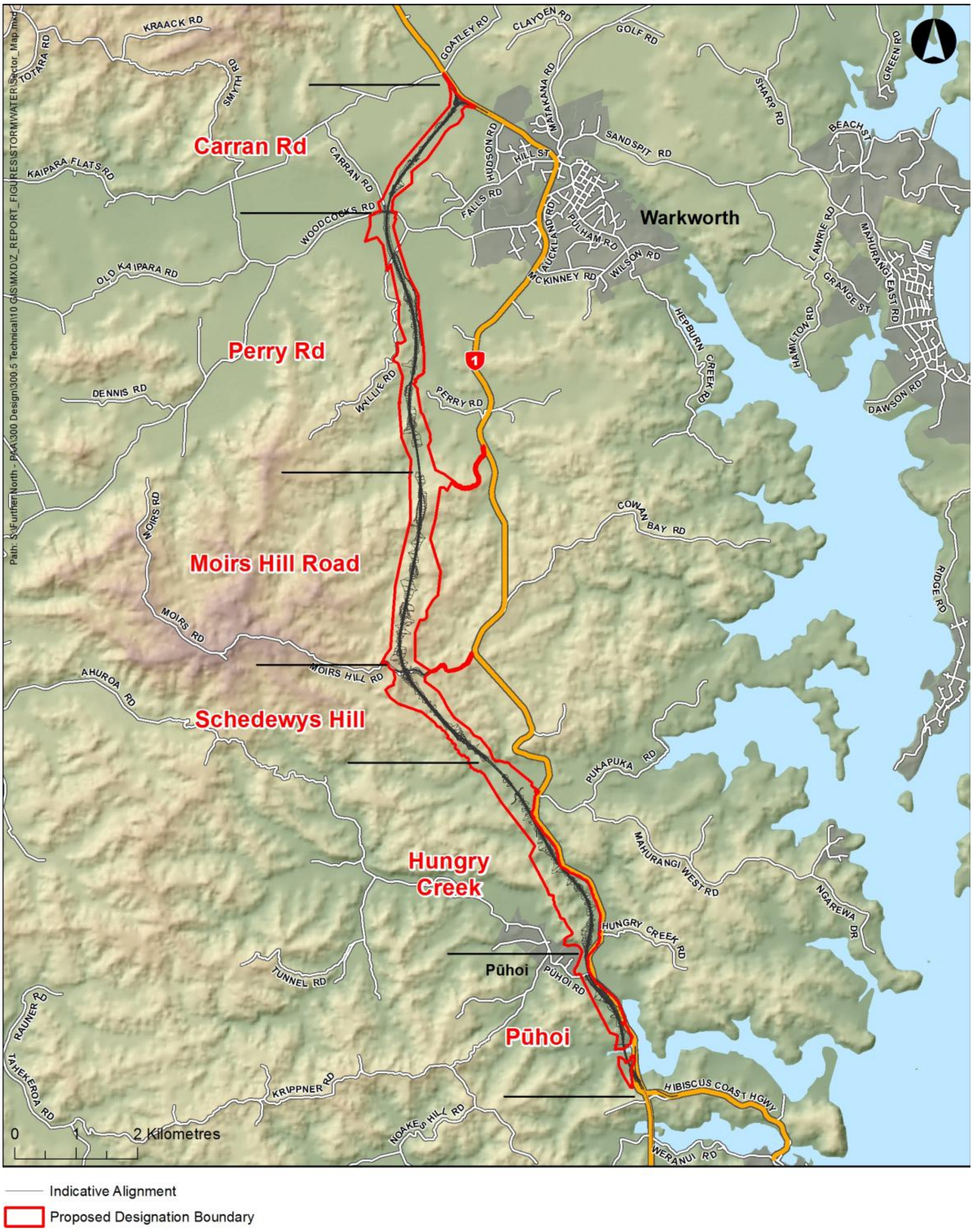

Figure 3: Project sectors

2.2.1 Pūhoi Sector

The Pūhoi Sector is within the Pūhoi River catchment and extends from the northern portals of the Johnstone's Hill tunnels to the vegetated escarpment north of Pūhoi Road. Key features of this Sector are:

- Approximately 2.4km in length;
- The alignment passes east of Pūhoi village and west of SH1;
- Two viaduct structures: Okahu Viaduct (crossing Okahu Creek) and Pūhoi Viaduct (crossing the Pūhoi River and Pūhoi Road);
- The alignment passes across the Coastal Marine Area at Okahu Creek;
- A 45m long retaining wall to the west of the northbound carriageway just north of Watson Road Overpass;
- Northbound off-ramp at Pūhoi Road and southbound on-ramp from existing SH1;
- Predominantly rural land-use with residential settlement to the west being part of Pūhoi village;
- A southern tie-in to Johnstone's Hill tunnels; and
- A connection between the Hibiscus Coast Highway and existing SH1 in both directions.

2.2.2 Hungry Creek Sector

The Hungry Creek Sector is within the Pūhoi River catchment and extends from the vegetated escarpment north of Pūhoi Road to Schedewys Hill. Key features of this Sector are:

- Approximately 3.8km in length;
- The alignment runs largely parallel to and west of SH1;
- A mechanically stabilised earth (MSE) slope close to SH1 in the vicinity of Hungry Creek Arts School;
- An overpass where the alignment passes over Watson Road (a private forestry road);
- A MSE slope and embedded concrete retaining wall north of Watson Road;
- One viaduct structure, Hikauae Viaduct (crossing Hikauae Creek); and
- Plantation forestry with some open grazing land and scattered rural-residential settlement.

2.2.3 Schedewys Hill Sector

The Schedewys Hill Sector is within the Pūhoi River catchment and extends from Schedewys Hill (just south of the SH1/Mahurangi West Road intersection) to Moirs Hill Road. Key features of this Sector are:

- Approximately 2km in length;
- The alignment passes to the west of SH1;
- One large viaduct structure, Schedewys Viaduct, with split level carriageway;

- Mostly plantation forestry with a small area of open pasture land to the south and some scattered rural-residential settlement at the northern extent of the sector, off Moirs Hill Road; and
- Moirs Hill Road is the catchment divide between the Pūhoi and Mahurangi catchments.

2.2.4 Moirs Hill Road Sector

The Moirs Hill Road Sector is within the Mahurangi River catchment and extends from Moirs Hill Road through to just south of Perry Road. Key features of this Sector are:

- Approximately 3.2km in length;
- The alignment passes to the west of SH1, skirting the western edge of the Pohuehue Scenic Reserve;
- Realignment of Moirs Hill Road;
- An underpass where the alignment passes beneath Moirs Hill Road; and
- Mostly plantation forestry with a small area of open pasture land at the northern extent of the sector.

2.2.5 Perry Road Sector

The Perry Road Sector is within the Mahurangi River catchment and extends from just south of Perry Road to the Woodcocks Road / Carran Road intersection. Key features of this Sector are:

- Approximately 4.4km in length;
- The alignment continues to the west of SH1, passing west of Genesis Aquaculture;
- An overpass where the alignment passes over Wyllie Road;
- Two viaduct structures: Perry Road Viaduct and Kauri Eco Viaduct (crossing the Mahurangi River Right Branch);
- At Wyllie Road the alignment crosses the Vector Limited High Pressure Gas Transmission Line connection to Warkworth;
- Realignment of a section of Woodcocks Road and the private access road connection to Wyllie Road; and
- Predominantly rural with areas of rural-residential development at Perry Road, Wyllie Road and Woodcocks Road.

2.2.6 Carran Road Sector

The Carran Road Sector is within the Mahurangi River catchment and extends from the Woodcocks Road / Carran Road intersection to the northern extent of the alignment at existing SH1 just south of Kaipara Flats Road. Key features of this Sector are:

- Approximately 2.7km in length;
- The alignment extends to the west of SH1, turning east to the SH1 northern tie-in;
- Termination of the motorway at a new roundabout at SH1;
- One large viaduct structure, Woodcocks Road Viaduct (crossing the Woodcocks Road / Carran Road intersection and the Left Branch of the Mahurangi River);

- One structure, the Carran Road Flood Bridge, to provide for the passage of floodwater in a 100 year flood event and farm access;
- A farm track underpass; and
- Predominantly farmland used for pastoral grazing with lifestyle blocks around Carran Road and a lifestyle subdivision at Viv Davie-Martin Drive.

2.3 Interchanges and tie-in points

The Project includes one main interchange and two tie-in points to the existing SH1, namely:

- The Pūhoi Interchange;
- Southern tie-in where the alignment will connect with the existing NGTR; and
- Northern tie-in where the alignment will terminate at a roundabout providing a connection with the existing SH1, just south of Kaipara Flats Road north of Warkworth.

3. Description of operational water management

Stormwater collected in motorway drainage systems will be conveyed by roadside drains, swales or pipes to wetlands for treatment prior to discharge to the natural environment. Constructed wetlands are our preferred stormwater treatment device and 27 are proposed for the Project. Sediment traps will provide initial capture of sediment generated from rock cuts upstream of the wetlands.

We have designed the permanent constructed wetlands to achieve:

- Treatment of all runoff from the motorway for 75% total suspended solids (TSS) removal.
- Extended detention for most areas of the motorway to reduce the potential for erosion of streams. Extended detention is not required in four locations where the Project discharges to the Pūhoi Estuary.

The Project proposes seven large viaducts and five bridges, of which nine are required because of stream / river crossings.

The Project proposes 40 culverts with three of the culverts as concrete arches. Two bridges, namely the Woodcocks Road Viaduct and the Carran Road Flood Relief Bridge, span the lower Mahurangi floodplain and have been designed to minimise effects on the floodplain.

The total length of culverts for permanent streams is 1,120m and for intermittent streams is 3,050m. Energy dissipation and erosion control will be provided for all stormwater outfalls. We provide fish passage in all but two culverts for permanent streams with upstream habitats (post-development). The two exceptions are where required upstream drop structures create a barrier to fish passage. We provide fish passage in culverts for all intermittent streams where the Project freshwater ecologists have identified potential for fish habitat upstream (based on the Freshwater Ecology Assessment Report).

Stream diversions have three typologies and approximate total lengths are as follows;

- Stream Diversion Type 1 – Lowland Stream with estimated length = 1,500m
- Stream Diversion Type 2 – Steep Stream with estimated length = 1,575m
- Stream Diversion Type 3 – Flow Channel with estimated length = 4,695m.

Stream diversions with natural stream forms (referred to as "Type 1 – Lowland Stream" and "Type 2 – Steep Stream") are proposed where the streams are permanent and support fish habitats, and also for those intermittent streams where there is potential for fish habitat upstream (based on the Freshwater Ecology Assessment Report).

This section describes the operational water systems to supplement the general description of the Project in Section 2. Operational water systems are detailed in the 'SW' Drawing series.

3.1 Stormwater management

3.1.1 Water quality

The proposed requirements for water quality treatment are summarised below:

- Water quality treatment is proposed for all new impervious areas, which include the motorway surface and rock cuts. Water quality treatment is also proposed for vegetated cuts;
- Removal of 75% TSS on a long-term average basis;
- Removal of contaminants associated with sediment such as particulate trace metals, particulate nutrients, oil, grease and bacteria; and
- Removal of gross litter and floatables such as oil and volatile hydrocarbons.

3.1.2 Water quantity

The proposed requirements for water quantity management are:

- Provide flood management through bypass or emergency overflow of 100 year Average Recurrence Interval (ARI) rainfall event flow; and
- Minimise erosion of streams by providing extended detention and controlled release of runoff generated in a rainfall event of 34.5mm[1] over a 24 hour period. Exceptions are where discharges are in close proximity to the Pūhoi Estuary. Due to the receiving tidal conditions where the estuary bed conditions continually change, we do not consider erosion to be an adverse effect at these discharge locations.

Detention of runoff for the 2 year, 10 year and 100 year ARI rainfall events for flood attenuation is not required (refer Section 8).

3.1.3 Wetlands

Constructed wetlands are our preferred stormwater treatment device for the Project, an outcome of the BPO assessment described in Section 7.3.

Stormwater collected in motorway drainage systems will be conveyed by roadside drains, swales or pipes to the constructed wetlands. The wetlands will be designed in accordance with TP10. During Project design, wetland locations will be refined with consideration given to landscape, constructability, maintenance and ecological values. The outlets from wetlands will be piped to adjacent streams.

The wetlands will be constructed and located off-line, i.e. not constructed in or on the bed of an existing stream.

A summary of the proposed stormwater treatment devices and their basic design parameters / requirements is provided in Table 2 (also provided in Drawing SW-151). A typical detail for the stormwater wetlands we propose is provided in Drawing SW-501.

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[1] ARC TP10 - *"Urban development has the effect of increasing the frequency and magnitude of floods, particularly during frequent small storm events … the ARC requires the runoff from a rainfall event of 34.5mm depth to be stored and released over a 24 hour period to minimise potential for stream channel erosion."*

Table 2: Summary of stormwater treatment devices

Catchment	Treatment device	Catchment area (ha) *[1]				Water quality treatment	Extended detention	Outlet erosion protection	Discharge location
		Pervious	Rock	Road	Total	Y/N	Y/N	Y/N	Ecological reference
Pūhoi	Wetland 64500	0.20	0.00	0.45	0.65	Y	N	Y	P1*[2]
	Wetland 63600	1.07	0.00	3.13	4.19	Y	N	Y	P3*[2]
	Wetland 62900	3.29	0.00	4.70	7.99	Y	N	Y	P4*[2]
	Wetland 62600	4.12	0.00	1.82	5.94	Y	N	Y	P4*[2]
	Wetland 61600	2.40	0.09	2.87	5.35	Y	Y	Y	P6
	Wetland 61400	3.07	0.01	1.80	4.89	Y	Y	Y	P6a
	Wetland 60600	3.77	0.11	2.03	5.91	Y	Y	Y	P8
	Wetland 60200	2.53	0.00	1.95	4.48	Y	Y	Y	P9
	Wetland 59600	0.51	0.00	1.15	1.66	Y	Y	Y	P10
	Wetland 59200	0.00	0.00	3.70	3.70	Y	Y	Y	P11
	Wetland 58800	2.89	0.34	2.36	5.59	Y	Y	Y	P11a
	Wetland 58200	0.56	0.01	4.62	5.18	Y	Y	Y	P11b/c
	Wetland 57300	3.13	0.43	2.59	6.15	Y	Y	Y	P11g
Mahurangi	Wetland 56200	3.24	0.19	1.45	4.89	Y	Y	Y	M13b
	Wetland 55500	5.10	0.76	2.53	8.39	Y	Y	Y	M13d
	Wetland 54500	1.80	0.39	2.94	5.13	Y	Y	Y	M15
	Wetland 53600	3.59	2.60	3.11	9.29	Y	Y	Y	M16

Catchment	Treatment device	Catchment area (ha) *1				Water quality treatment	Extended detention	Outlet erosion protection	Discharge location
		Pervious	Rock	Road	Total	Y/N	Y/N	Y/N	Ecological reference
	Wetland 53100	0.00	0.00	1.32	1.32	Y	Y	Y	M16
	Wetland 52200	3.90	0.42	3.20	7.51	Y	Y	Y	M18/19
	Wetland 51300	1.90	0.00	2.95	4.85	Y	Y	Y	M19c
	Wetland 50300	2.34	0.11	3.09	5.54	Y	Y	Y	PA500A
	Wetland 49900	0.00	0.00	1.14	1.14	Y	Y	Y	PA100A
	Wetland 49400	0.00	0.00	2.89	2.89	Y	Y	Y	M22
	Wetland 48900	2.01	0.00	1.11	3.12	Y	Y	Y	M23/24
	Wetland 48400	0.00	0.00	1.01	1.01	Y	Y	Y	Carran Rd Flood Relief Bridge
	Wetland 47700	1.49	0.00	4.14	5.63	Y	Y	Y	M23b
	Wetland 800SH1S	0.00	0.00	1.20	1.20	Y	Y	Y	SH1-700

*1 Areas (ha) are plan areas.
*2 Short stream connecting to Coastal Marine Area (CMA)

3.1.4 Sediment traps

Sediment traps are proposed for the Project in drains at the base of rock cut faces. These sediment traps are bespoke treatment devices that will capture sediment generated from rock cuts. On the NGTR project, cut faces have yielded larger sediment loads than anticipated over the initial years since becoming operational in 2009.

Section 7.3.8 presents the sediment traps in more detail from a BPO perspective. The locations and extent of the sediment traps are shown in the Project drawing set. A typical detail for a sediment trap is shown on Drawing SW-307.

3.1.5 Vegetated roadside drains

A number of ancillary roads will be constructed or upgraded as part of the Project. These include the proposed access road off Wyllie Road, the access road to the Perry Road Viaduct, upgrades to Moirs Hill Road, and roads associated with underpasses.

Conveyance of water runoff from these ancillary roads constructed or upgraded as part of the Project will be via vegetated roadside drains that will discharge to existing streams. These drains are commonly used around New Zealand and are generally "U" shape in profile and quite deep. Their primary function is capture 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 ancillary roads have low traffic volumes and we consider vegetated roadside drains to be the BPO (see Section 7.3.9).

3.2 Bridges and culverts

Where the Project crosses existing streams (permanent and intermittent) we propose bridges and culverts to provide conveyance of normal flows and flood waters from one side of the motorway to the other, whilst minimising the effect on the existing flow and the ecological condition of the waterways.

The indicative alignment for the Project proposes seven large viaducts and five bridges, of which nine are required because of stream / river crossings. The Project also proposes 40 major culverts with three of the culverts being concrete arches. The bridges and culverts and their key characteristics are summarised in Table 3 (and are also provided in relation to other operational water management structures in Drawing SW-150). The table also includes summary information on the ecological status of the streams (permanent or intermittent), fish passage provided at culverts and stream diversion lengths and types specified. The information provided has been developed in collaboration with the Project freshwater ecologists. Refer to the Freshwater Ecology Assessment Report for further information and assessment of the effects of the Project on freshwater ecology.

Two bridges, namely the Woodcocks Road Viaduct and the Carran Road Flood Relief Bridge, span the lower Mahurangi floodplain and have been designed to minimise effects on the floodplain.

The total length of culverts for permanent streams is 1,120m, and for intermittent streams is 3,050m.

Ancillary roads that require new culverts or extensions to existing culverts include:

- SH1, requiring upgrades to three culverts (refer Table 3);
- Moirs Hill Road realignment, requiring extensions to existing culverts (not detailed in consent design);
- Access road off Wyllie Road, requiring new culverts and a minor bridge (refer Table 3);
- Access road to Perry Road Viaduct, requiring culvert upgrades (not detailed in consent design); and
- Roads associated with underpasses (not detailed in consent design).

Sections 7.6 and 7.7 describe our BPO assessment for bridges and culverts, respectively. All bridge and culvert locations and typical details are shown in the drawings set.

3.3 Stream diversions

Stream diversions are required where a natural stream channel will be affected by the construction of the motorway. The diversions either convey flow to a culvert, under a bridge, or to another stream or water body. Our mitigation objective for stream diversions is to recreate streams and habitats to replicate as much as possible the natural state and habitats of the steams that existed prior to the Project.

The number of stream diversions required has been reduced in consultation with the Project Road Design and Geotechnical teams. The BPO assessment for stream diversions is detailed in Section 7.9.

We have developed three stream diversion typologies based on the requirements summarised in this Report and described in detail in Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo. The three typologies are:

- 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.

These three typologies are discussed in more detail in Section 7.9 and are shown on Drawings SW-401, SW-402 and SW-403.

The total lengths as summarised from Table 3 are as follows:

- Stream Diversion Type 1 = 1,500m
- Stream Diversion Type 2 = 1,575m
- Stream Diversion Type 3 = 4,695m

All culverts are assumed to require 10m of stream diversion upstream and downstream to tie back into the existing stream as they will normally be constructed off-line (i.e. out of the stream in the dry and protected from flooding of the stream). The construction of culverts is described in the Construction Water Assessment Report.

3.4 Erosion control at outlets

Energy dissipation structures will be used to minimise erosion from all wetland outfalls and culvert outlets.

Wetland outfalls will incorporate erosion protection measures to minimise 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.

Culvert outlets will incorporate energy dissipation measures as summarised in Table 3. Section 7.7.3 presents the BPO for the proposed energy dissipation structures at culvert outlets. For details of the energy dissipation for culvert outlets refer to Drawings SW-301, SW-302 and SW-303.

Table 3: Summary of bridges[*1], culverts[*2] and stream diversions

Stream				Cross drainage						Stream diversion[*4]		
Catchment	**Stream**	**Ecological status**	**Fish type**	**Culvert / bridge**	**Diameter (mm)**	**Length[*3] (m)**	**Designed fish passage**	**Debris management**	**Energy dissipation structure**	**Type 1 (m)**	**Type 2 (m)**	**Type 3 (m)**
Pūhoi	**ON INDICATIVE MOTORWAY ALIGNMENT**											
	P1	Estuarine	"Swimming"	BRIDGE - OKAHU VIADUCT	-	-	-	-	-	76		
	P2	Intermittent	None	Culvert 63800	1600	165	None	Relief Inlet	SAF Stilling Basin			61
	P3	Intermittent	None	Culvert 63500	1800	262	None	Relief Inlet	SAF Stilling Basin			163
	P3a	Intermittent	None	Culvert 63000	1350	92	None	None	SAF Stilling Basin			90
	P4	Estuarine	"Swimming"	BRIDGE - PŪHOI VIADUCT	-	-	-	-	-			
	P5	Intermittent	None	Culvert 61900	1600	99	None	None	Riprap Basin			660
	P6	Intermittent	None	Culvert 61600	1800	62	None	None	SAF Stilling Basin			621
	P6a	Permanent	None	Culvert 61300	1200	75	None	None	SAF Stilling Basin			28
	P7	Permanent	None	Culvert 61100	1350	81	None	Relief Inlet	SAF Stilling Basin			20

Stream				Cross drainage						Stream diversion[*4]		
Catchment	**Stream**	**Ecological status**	**Fish type**	**Culvert / bridge**	**Diameter (mm)**	**Length [*3] (m)**	**Designed fish passage**	**Debris management**	**Energy dissipation structure**	**Type 1 (m)**	**Type 2 (m)**	**Type 3 (m)**
	P8	Intermittent	None	Culvert 60800	2550	127	None	Debris Rack and culvert sized to pass 100 year ARI	SAF Stilling Basin			42
	P9	Permanent	"Climbing"	Culvert 60200 ARCH	Arch (7315 Span, 3658 Height)	104	Natural Bed	Debris Rack and culvert sized to pass 100 year ARI	Riprap Basin		32	
	P9b	Intermittent	None	Culvert 59900	1200	65	None	None	SAF Stilling Basin			20
	P9a	Intermittent	None	Culvert 59800	1600	121	None	Relief Inlet	SAF Stilling Basin			20
	P10	Permanent	None	BRIDGE - HIKAUAE VIADUCT	-	-	-	-	-			
	P10a	Intermittent	None	Culvert 59400	1200	55	None	None	SAF Stilling Basin			20
	P11	Permanent	"Swimming"	BRIDGE - SCHEDEWYS VIADUCT	-	-	-	-	-			
	P11a	Intermittent	None	Culvert 58700	1600	116	None	None	SAF Stilling Basin			122
	P11b/c	Permanent	None	Culvert 58400	1600	146	None	Relief Inlet	SAF Stilling Basin			226

Stream				Cross drainage						Stream diversion[*4]		
Catchment	**Stream**	**Ecological status**	**Fish type**	**Culvert / bridge**	**Diameter (mm)**	**Length [*3] (m)**	**Designed fish passage**	**Debris management**	**Energy dissipation structure**	**Type 1 (m)**	**Type 2 (m)**	**Type 3 (m)**
	P11f	Intermittent	None	Culvert 57600	1600	137	None	Relief Inlet	SAF Stilling Basin			439
	P11g	Intermittent	None	Culvert 57400	1350	96	None	None	SAF Stilling Basin			304
	P12	Intermittent	None	Culvert 57200	1600	235	None	Relief Inlet	SAF Stilling Basin			447
Mahurangi	M13	Intermittent	None	Culvert 56700	1600	123	None	None	SAF Stilling Basin			20
	M13a	Intermittent	None	Culvert 56400	1200	97	None	Relief Inlet	SAF Stilling Basin			44
	M13b	Intermittent	None	Culvert 56100	1200	84	None	None	SAF Stilling Basin			42
	M13d	Permanent	"Climbing"	Culvert 55300	2550	81	Baffle	Relief Inlet	Modified SAF Stilling Basin		1486	
	M14			STREAM DIVERSION								605
	M15	Permanent	"Climbing"	Culvert 54700 ARCH	Arch (8534 Span, 4267 Height)	258	Natural Bed	Debris Rack and culvert sized to pass 100 year ARI	Riprap Basin		20	
	M15a	Intermittent	None	Culvert 53800	1600	70	None	None	Riprap Basin			335

Stream				Cross drainage						Stream diversion*4		
Catchment	Stream	Ecological status	Fish type	Culvert / bridge	Diameter (mm)	Length *3 (m)	Designed fish passage	Debris management	Energy dissipation structure	Type 1 (m)	Type 2 (m)	Type 3 (m)
	M16	Permanent	"Climbing"	BRIDGE - PERRY ROAD VIADUCT	-	-	-	-	-			
	M16a	Intermittent	None	Culvert 53000	1600	175	None	Relief Inlet	SAF Stilling Basin			155
	M18/19	Permanent	"Swimming"	BRIDGE - KAURI ECO VIADUCT	-	-	-	-	-	289		
	M19a	Intermittent	None	Culvert 51900	1200	77	None	None	SAF Stilling Basin			20
	M19b	Intermittent	None	Culvert 51600	1200	84	None	Relief Inlet	SAF Stilling Basin			111
	M19c	Intermittent	None	Culvert 51300	1800	172	None	Relief Inlet	SAF Stilling Basin			20
	M21a	Intermittent	"Climbing"	Culvert 51000	1600	124	Baffle	Relief Inlet	Modified SAF Stilling Basin		37	
	M21b	Permanent	None	Culvert 50800	1200	94	None	Relief Inlet	SAF Stilling Basin			20
	M21c	Intermittent	"Swimming"	Culvert 50500	1200	92	Baffle	None	Modified SAF Stilling Basin	20		
	M21d	Intermittent	"Swimming"	Culvert 50200	1600	109	Baffle	Relief Inlet	Riprap Basin	73		

Stream				Cross drainage						Stream diversion [*4]		
Catchment	Stream	Ecological status	Fish type	Culvert / bridge	Diameter (mm)	Length [*3] (m)	Designed fish passage	Debris management	Energy dissipation structure	Type 1 (m)	Type 2 (m)	Type 3 (m)
	M21e	Intermittent	"Swimming"	BRIDGE - WYLLIE ROAD OVERPASS	-	-	-	-	-			
	M22	Permanent	"Swimming"	Culvert 49500 ARCH	Arch (7315 Span, 3658 Height)	104	Natural Bed	Debris Rack and culvert sized to pass 100 year ARI	Riprap Basin	31		
	M23/24	Permanent	"Swimming"	BRIDGE - WOODCOCKS ROAD VIADUCT	-	-	-	-	-			
	-	Permanent	"Swimming"	BRIDGE - CARRAN ROAD FLOOD RELIEF BRIDGE	-	-	-	-	-	344		
	M23a	Permanent	"Swimming"	Culvert 48000	1350	45	None	None	Riprap Basin	220		
	M23b	Permanent	"Swimming"	Culvert 47700	1350	71	None	None	Riprap Basin	145		
	M23c	Permanent	"Swimming"	Culvert 47400	1600	60	Baffle	None	Riprap Basin	51		
	M23d	Intermittent	"Climbing"	Culvert 47200	1200	61	Baffle	None	Modified SAF Stilling Basin	191		
	ON PROPOSED EASTERN LINK TO WARKWORTH											
	SH1-700	Intermittent	None	Culvert 700SH1S	1600	69	None	None	SAF Stilling Basin			40

Stream				Cross drainage						Stream diversion*4		
Catchment	Stream	Ecological status	Fish type	Culvert / bridge	Diameter (mm)	Length *3 (m)	Designed fish passage	Debris management	Energy dissipation structure	Type 1 (m)	Type 2 (m)	Type 3 (m)
	ON PROPERTY ACCESS ROAD (WYLLIE ROAD)											
	PA100A	Intermittent	"Swimming"	Culvert 100A	1050	22	Baffle	None	Riprap Basin	20		
	PA200A	Intermittent	"Swimming"	Culvert 200A	900	21	Baffle	None	Riprap Basin	20		
	PA500A	Intermittent	"Swimming"	Culvert 500A	900	33	Baffle	Relief Inlet	Riprap Basin	20		
	PA900A	Permanent	"Swimming"	MINOR BRIDGE - PROPERTY ACCESS ROAD	-	-	-	-	-			
Pūhoi												
	ON EXISTING STATE HIGHWAY 1											
	P6	Intermittent	None	SH1-P6	1200	22	None	None	To be detailed in design phase			
	P8	Intermittent	None	SH1-P8	825	43	None	None	To be detailed in design phase			
	P9	Permanent	"Climbing"	SH1-P9	1600	30	Baffle	None	To be detailed in design phase			

*1 Excludes Moirs Hill Road and other access roads/tracks where no design has been completed at this stage.
*2 Only bridges associated with streams are included.

*3 Lengths (m) are measured in plan (horizontally). Actual lengths may differ and are longer due to the slopes.
*4 Stream diversion types are described in detail in Section 7.9 and are shown on Drawings SW-401, SW-402 and SW-403.

4. Existing environment

The Project traverses the Pūhoi and Mahurangi catchments. The Project area is largely characterised by steeper rolling hill country with interconnected ridge and valley systems in the south and central sectors. The terrain changes to low undulating country in the northern parts of the Mahurangi catchment.

The geology of the Project area consists of predominantly Pakiri Formation with some areas of Northern Allochthon, and alluvium in the northern sectors.

In the Pūhoi catchment the receiving environments are the tributaries and main streams of the Hikauae Creek and Pūhoi River, and ultimately the Pūhoi Estuary. In the Mahurangi catchment the receiving environments are the tributaries and main streams of the Mahurangi River left and right branches and ultimately the Mahurangi Harbour. The indicative alignment crosses a mixture of permanent and intermittent streams and rivers. The streams vary from natural streams with good riparian vegetation to farm drains. The streams have rock outcrops in places, but also consist of soft bottom streams.

The Mahurangi catchment water quality is generally good with slightly elevated TSS, turbidity and phosphorus according to previous studies and existing Auckland Council (AC) data. Metal and hydrocarbon concentrations are acceptable and below guidelines. Monitoring we have undertaken for the Project presents a similar picture of generally good water quality in both the Mahurangi and Pūhoi catchments with some TSS, turbidity and phosphorus results elevated above guidelines and metals and hydrocarbon concentrations being low. Sediment quality in the streams is good with little contamination in evidence.

The aquatic biological data described in the Freshwater Ecology Assessment Report indicates that the quality of freshwater aquatic habitats along the indicative alignment is typical of those found in the Auckland region and is primarily determined by the land-use in the associated catchment.

The Mahurangi Harbour is a drowned river valley, with vast intertidal flats and sub-tidal areas present in its middle to lower reaches. The Pūhoi Estuary is a mature, highly infilled, tidal lagoon with extensive intertidal flats fringed by dense mangrove stands and saltmarsh that provide important habitat for indigenous birds and fish. The marine ecological values of the affected estuaries are described in the Marine Ecology Assessment Report.

Sediment is a key existing environmental issue in the Mahurangi estuary with sediment deposition from surrounding catchment land-uses currently impacting on the estuary. Water quality is good in the Mahurangi estuary with most parameters within guidelines except for TSS and phosphorus levels. Sediment quality in the lower estuaries is good with little contamination in evidence, except for elevated Cu in the upper Mahurangi estuary.

Existing catchment uses and values include aquatic ecology, cultural values including food gathering, stock watering and irrigation, aquaculture (fish farm), water for potable water supply and other consented uses, and recreation use including contact recreation, pleasure boating, amenity based recreation activities and fishing.

Existing SH1 culverts in the Pūhoi Sector and Hungry Creek Sector and water supply for the fish farm and Warkworth in the Mahurangi catchment are the most significant water infrastructure downstream of the Project. Otherwise there is little or no water infrastructure within the vicinity of the Project.

In this section, we describe the existing environment to provide a context for our assessment of effects. The section includes descriptions of the two main catchments, topography, geology, flooding, water quality, existing infrastructure and existing catchment uses and values. The ecology of the existing environment is described in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

4.1 Catchments

The catchments and Project alignment are shown in Figure 4. The Project traverses two major river catchments; the Pūhoi and the Mahurangi. Moirs Hill Road represents the approximate catchment divide. The highest motorway elevation is approximately 186m reduced level (RL).

Initially the alignment passes parallel to the tidally influenced areas of the Pūhoi River and crosses the Pūhoi River itself. The alignment then rises parallel to and then crosses the Hikauae Creek, a major sub-catchment of the Pūhoi River. In the Mahurangi catchment the alignment crosses into the Mahurangi River Right Branch before crossing the Mahurangi River Left Branch at Woodcocks Road. The alignment crosses numerous tributaries at these streams in both catchments.

The Pūhoi catchment area is 5,257ha as measured at the furthermost downstream end of the Project extent. It is characterised by moderate and steep slopes, which are occupied mostly with plantation forest and pastoral farming.

The Mahurangi catchment area is 3,828ha as measured at the furthermost downstream end of the Project influence (downstream of Falls Road). The headwaters of the Mahurangi River Right Branch catchment are on the northern slopes of Moirs Hill. North of Moirs Hill Road the Project alignment crosses numerous steeply incised gulleys. North of Perry Road the valleys become undulating with tributaries flowing to the Mahurangi River Right Branch. Just north of Woodcocks Road a further series of gentler valleys and streams drain to the Mahurangi River Left Branch and the main Mahurangi River.

In relation to the Project Sectors previously described in Section 2, the Pūhoi catchment contains the Pūhoi, Hungry Creek and Schedewys Hill Sectors; whereas the Mahurangi catchment contains the Moirs Hill, Perry Road and Carran Road Sectors.

The Mahurangi River flows to the Mahurangi Harbour. The Mahurangi Harbour is a drowned river valley, with vast intertidal flats and sub-tidal areas present in its middle to lower reaches. It contains many small bays and upper estuaries, which dry during the tidal cycle and are comprised of soft muddy sediments. The remainder of the harbour has large areas of permanent water and less soft sediments.

The Pūhoi estuary is further south and is a much smaller and narrow tidal estuary. The Pūhoi Estuary is a mature, highly infilled, tidal lagoon with extensive intertidal flats fringed by dense mangrove stands and saltmarsh that provide important habitat for indigenous birds and fish.

The marine ecological values of the affected estuaries are described in the Marine Ecology Assessment Report.

The extensive network of rivers and streams throughout the Pūhoi and Mahurangi catchments reflects the relative complexity of the landform along much of the Project alignment. A selection of stream locations is identified in Figure 5 and the relevant photos are shown in Figure 6 to illustrate typical streams. The indicative alignment crosses a mixture of permanent and intermittent streams, which are described in more detail in the Freshwater Ecology Assessment Report.

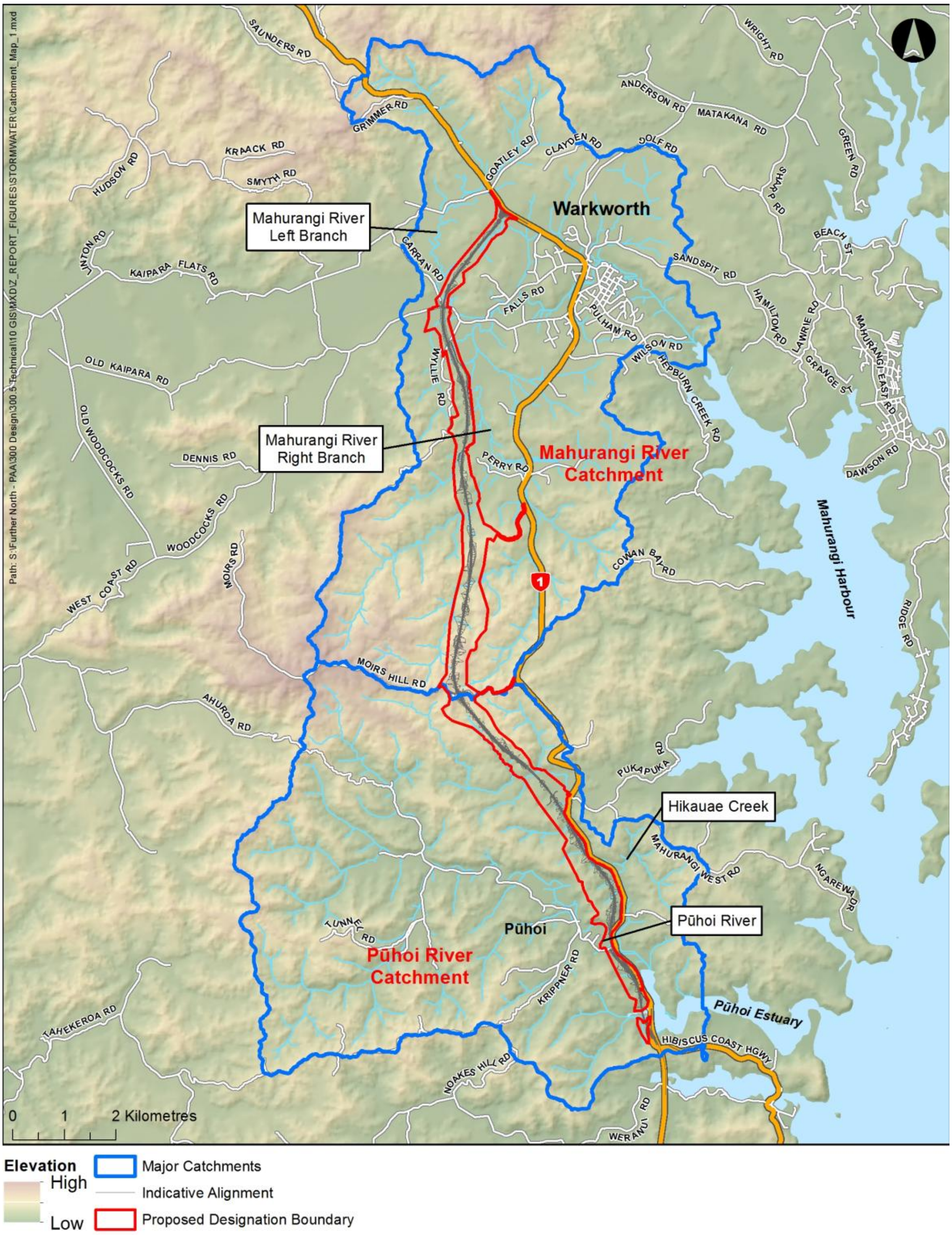

Figure 4: Pūhoi and Mahurangi Catchments

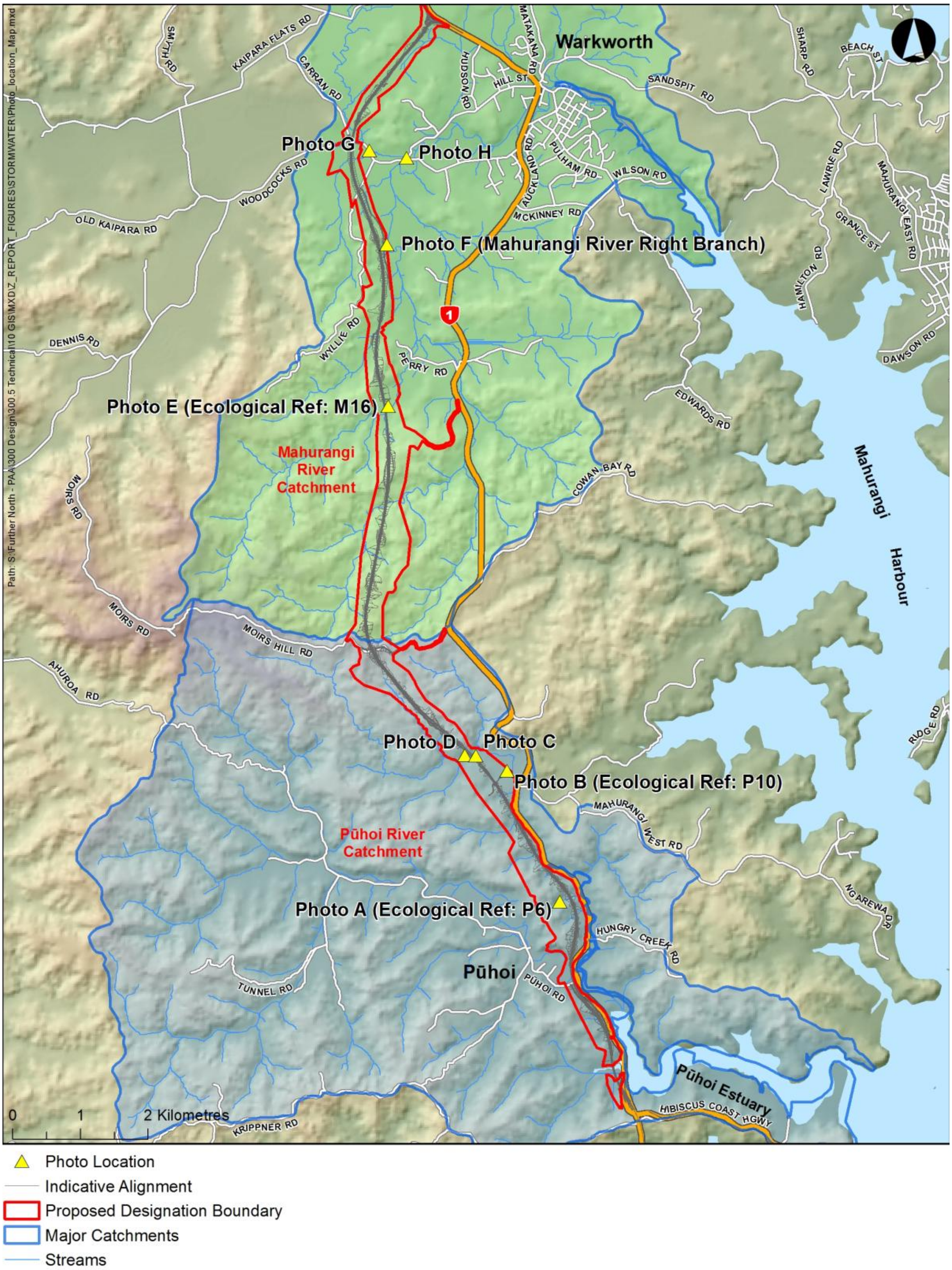

Figure 5: Photo location map

Figure 6: Existing environment photos

4.2 Geology and geomorphology

The Geotechnical Engineering Appraisal Report provides a detailed description of the Project geology. The majority of the area is underlain by the Pakiri Formation part of the Waitemata Group, which comprises of sandstones and mudstones. Also present within the Project area is the Northern Allochthon formation (previously known as Onerahi Chaos), which are significantly weaker, highly sheared mudstones, siltstones, sandstones and limestones. Thrust faults define many of the boundaries between Pakiri Formation and Northern Allochthon sheets. There are also areas of alluvium in the flatter northern sectors.

The streams vary from natural streams with good indigenous riparian vegetation to farm drains. The natural streams vary from steep streams to lowland flat streams. The streams are often incised into the Pakiri geology with rock cascades (falls) observed in steep tributaries and rock outcrops visible at locations along main branches.

In other locations, the streams are in soil and weathered rock materials and are typical of soft bottom streams. Pools and riffles commonly form in these natural streams.

The streams in the Pūhoi and Mahurangi catchments do not carry substantial bed load material, with bottom sediments varying from silts to gravels, in addition to bedrock substrates.

4.3 Flooding

Flooding is an existing issue in the lower Mahurangi catchment including in parts of Warkworth. Auckland Council is developing flood management models for the Mahurangi and Warkworth area to define hazards and to plan for mitigation options. The flood hazard areas in the Carran Road Sector are shown in Figure 7 for the existing 100 year ARI flood overlaid with the indicative Project alignment. The flood hazard areas are based on the Auckland Council rapid flood hazard models (refer to Section 6.3 for details).

The key areas of flooding that interact with the Project are as follows:

- Mahurangi River Left Branch in the vicinity of Woodcocks Road.
- Secondary flow path from Mahurangi River Left Branch up the flat valley to the north following the indicative Project alignment. The secondary flow path has depths up to 3m with water levels grading from 35.5m RL to 35m RL at the north. The secondary flow path is estimated to convey a peak 100 year ARI rainfall event flow of approximately 90m^3/s. The secondary flow path flows north before returning via the Hudson Road area to the Mahurangi River downstream of Falls Road. During normal flows, the farm drains in this area flow both north and south. Essentially the secondary flow path conveys flood flow out of the Mahurangi River Left Branch into an adjacent sub-catchment and back into the Mahurangi River.

The secondary flow path was validated by anecdotal evidence gathered from the farm manager during a site visit we undertook in February 2013. In particular, the farmer observed the secondary flow path flooding and flowing to the north during the Anniversary Weekend flooding in 2011, an event estimated as a 20 year ARI rainfall event, based on the rainfall record at the Warkworth gauge. In the absence of further information, we rely on this anecdotal evidence for confirmation of this existing flooding pattern.

Flooding is not an issue in the Project area of the Pūhoi catchment, with the exception of the nearby Pūhoi township where the Auckland Council flood maps suggest there is flooding of dwellings, refer Drawing SW-103. The Pūhoi Viaduct spans the floodplain and is significantly larger than the existing SH1 bridge across the river and therefore will not impact on this existing flooding issue.

The 100 year ARI flood plain for both the Mahurangi and Pūhoi catchments is shown on the drawing set.

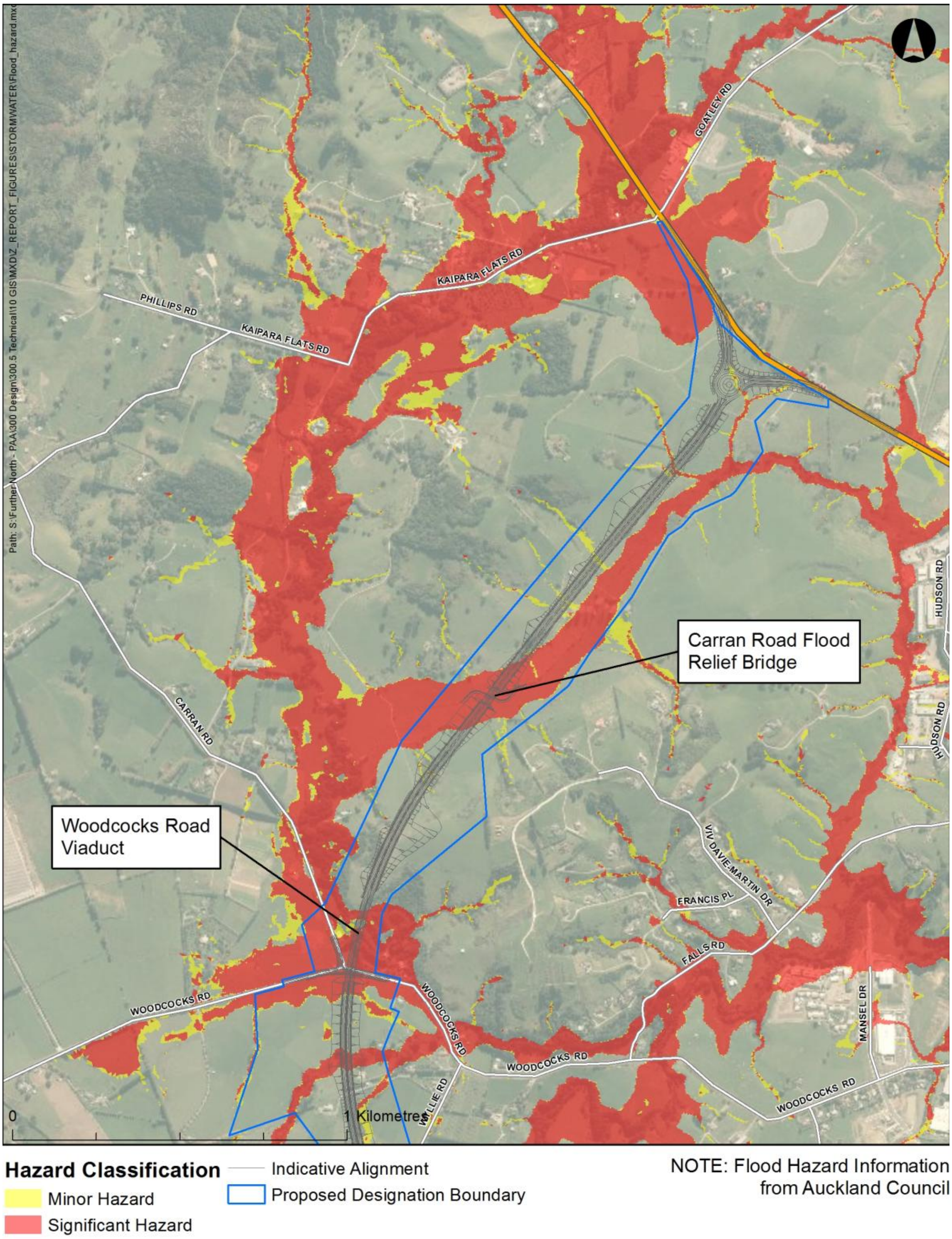

Figure 7: Flood Hazard Classification

4.4 Water quality

We have characterised water quality in the Project catchments based on literature, existing data and monitoring, and summarise it below. A full description of the existing water quality is detailed in Water Assessment Factual Report 4: Water Quality Monitoring Report.

We collected water quality data for the Project from thirteen sites. Figure 8 shows the location of these water monitoring sites. Two of these sites were located at the mouths of the two streams in brackish waters and the other 11 were freshwater sites.

Overall, the Auckland Council data and Project monitoring data show that water quality is reasonably good across the freshwater catchments. Data gathered for the Project presents a similar picture of water quality to that provided by Auckland Council data and the data did not indicate significant differences between the Mahurangi and Pūhoi catchments. Suspended solids and turbidity are generally elevated and therefore the streams have generally low clarity. Suspended solids are a stressor on the estuarine environment. Metals are generally in low concentrations and hydrocarbon concentrations are very low. Nutrients (nitrogen and phosphorus) are occasionally elevated above guidelines. In general the exceedances of guidelines are not by large orders of magnitude.

Saline water quality is good in the Mahurangi Estuary with slight elevations of TSS and nutrients. No water quality data is available from the Pūhoi Estuary, however we anticipate it also has good water quality, because the freshwater monitoring indicates that both catchments water quality are similar and the sediment quality is also currently similar.

Sediment quality is good in both the fresh and marine Mahurangi and Pūhoi catchment, with the exception of the upper Mahurangi which has elevated copper.

Overall, when considering the average water quality data the Mahurangi River is considered to be suitable for preservation of aquatic ecology values and suitable for stock watering, irrigation and fish farming uses. The catchments are however sensitive to further additions of sediment and nutrients primarily as these are already elevated and/or causing concern.

The catchment will continue to be sensitive to sediment inputs. Due to the current low concentrations of metals and hydrocarbons, the environment will have a lower sensitivity to these contaminants.

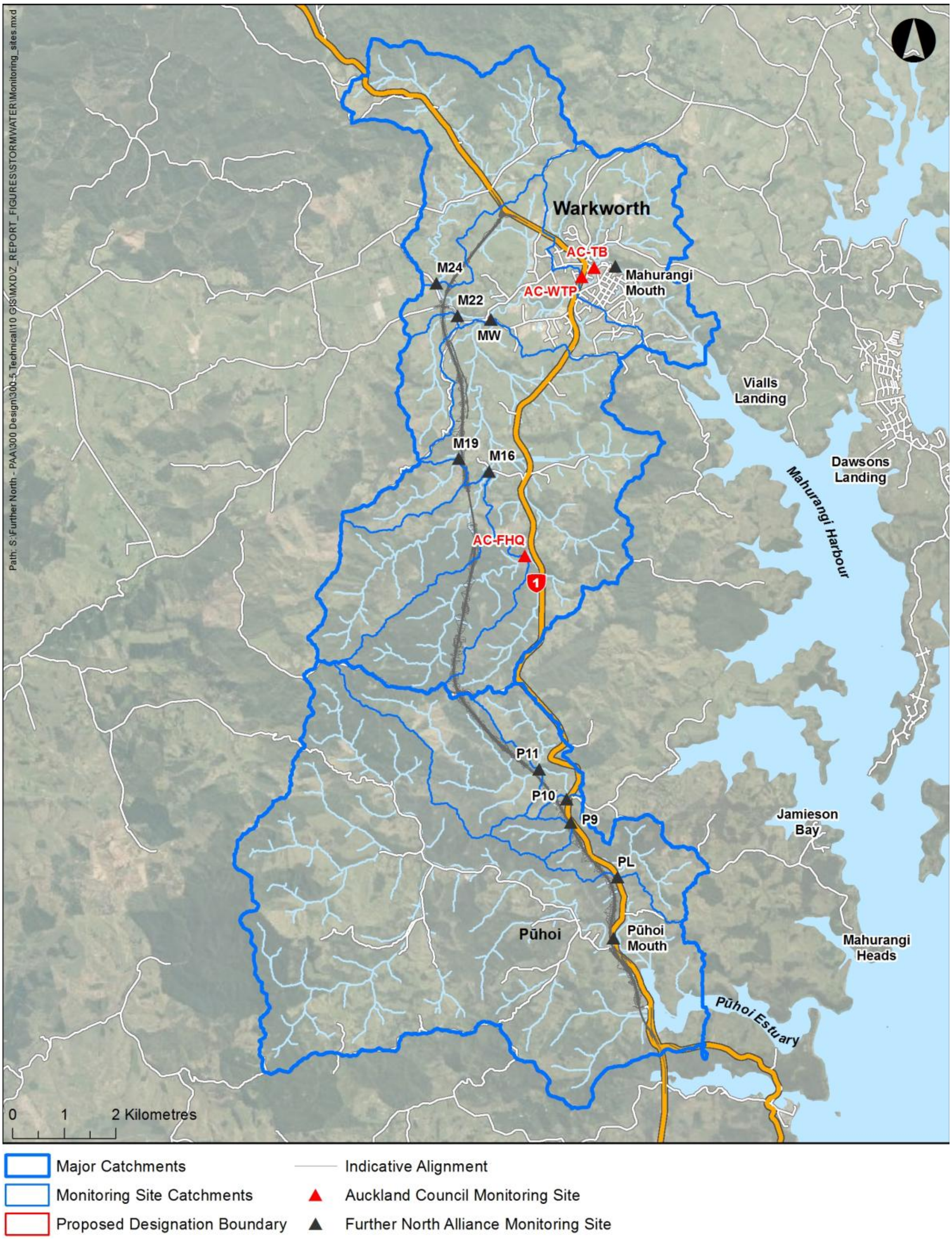

Figure 8: Water quality monitoring sites

4.5 Existing catchment uses and values

The existing landform, geology and land-use within the Pūhoi and Mahurangi catchments affect the existing water and sediment quality. Within the catchments the rivers and streams have a range of values and uses. The Pūhoi and Mahurangi catchments have the following potential uses and values (which are discussed in Table 4 below):

- Supporting aquatic ecology;
- Cultural values including food gathering;
- Use for stock watering and irrigation;
- Use for aquaculture (fish farm);
- Use of water for potable water supply and other consented uses; and
- Recreation use including contact recreation, informal boating and bankside amenity based recreation activities and fishing.

Table 4: Existing freshwater catchment land-uses and values

Value or Use	Details
Aquatic ecology	The nature of the existing freshwater ecology and the assessment of effects of the Project on aquatic ecology, are provided in the Freshwater Ecology Assessment Report. The in-stream water quality is a significant control on aquatic ecology. As such, water quality has been compared to guideline values intended to protect aquatic ecology values.
Cultural Values	Cultural values include use of freshwater resources for food and their general cultural history and significance. These matters are covered in the Cultural Assessment Report.
Stock watering	Stock watering is provided in the catchment through direct stock access to waterways or through stock watering systems reticulated from streams. Stock water takes from surface waters would generally be permitted activities so no consents would be held.
Irrigation	Irrigation activities include horticulture and small scale pasture irrigation. No resource consents exist for irrigation from surface water within the Project area. The only consent for irrigation in the Mahurangi catchment is for irrigation of a 1.5ha nursery, where water is taken from a tributary that will be unaffected by the Project (consent 21828). Permitted takes for small scale irrigation may however be undertaken in areas the Project could affect but no records are kept by Auckland Council to determine whether any exist or not.
Aquaculture	Genesis Aquaculture fish farm is located within the Mahurangi catchment and takes water from a tributary of the Mahurangi adjacent to the fish farm and downstream of the proposed Kauri Eco Viaduct.
Water supply from surface water	Watercare holds consent for the take of surface water from the lower Mahurangi to provide for the Warkworth town water supply. Watercare holds consent for the taking of surface water (from the River) and a further consent for the taking of ground water. It is in the process of developing a water supply bore. Watercare anticipates the bore will be in operation from 2016 It is envisaged the bore will be the primary water supply for Warkworth and the surface water will be a back-up supply, but the bore is still in development, and therefore the bore source is not guaranteed at this point. No other consented surface water takes are known, water may be abstracted under the permitted rule.
Recreational activities	Recreational activities include contact recreation, kayaking, fishing and general amenity use of streams from accessible reserve areas.

Value or Use	Details
	We have identified no bathing areas within the freshwater catchments in proximity to the indicative Project alignment. Many small streams are in private land and are unlikely to be used for contact recreation because they are generally small and shallow. The lower reaches of the Mahurangi and Pūhoi have areas where access can be gained. Occasional informal use of the streams for bathing may occur. There is a popular swimming hole at Falls Road on the Mahurangi River. Kayaking is a popular recreational activity in the lower Pūhoi River Estuary. Fishing may also occur in lower areas of the river and the estuaries, however we have identified no specific data to indicate whether fishing does occur. Fishing, with the exception of eeling, is less likely to occur in streams higher in the catchment as the streams are small. Public access is limited in most of the Hikuaea Creek and upper streams of the Mahurangi. The watercourse is visible to property owners and also to the public at bridge locations. The lower Mahurangi has areas within Warkworth where the general public can view the watercourse. The main recreational opportunities occur along the banks of the tidal area of the Mahurangi estuary.

The estuarine and harbour environments have their own range of users and values. Details of these values are provided in Table 5.

Table 5: Existing estuarine and harbour catchment uses and values

Value or Use	Details
Marine aquatic ecology	The nature of the existing ecology and assessment of effects of the Project on the marine aquatic ecology are provided in Marine Ecology Assessment Report. The estuarine and harbour water quality is a significant influence on aquatic ecology. As such water quality has been compared to guideline values intended to protect marine aquatic ecology values.
Cultural Values	Cultural values include use of marine aquatic ecology resources for food and the general cultural history and significance of the coast, estuary and harbour. These matters are covered in the Cultural Assessment Report.
Aquaculture	Oyster farms are located in the Mahurangi Harbour and are detailed in the Marine Ecology Assessment Report. There are currently 42 Auckland Council resource consents granted for marine farming activities in the Mahurangi. There are no oyster farms or other aquaculture within the Pūhoi estuary.
Other consented activities	Other than the marine farming consents there are few other activities with resource consents associated with the estuarine environments recorded in information provided by Auckland Council. The NZTA has consents for some earthworks and coastal reclamation associated with the existing SH1. There is a consent for the network discharge of stormwater from Warkworth and a discharge consent for the Warkworth waste water treatment plant. The Project activities are not considered likely to affect any of these consented activities.
Recreational activities	Recreational activities include contact recreation, kayaking, boating (motor and sail), fishing and food gathering and general amenity use of coastal areas. The marine areas of the Mahurangi and Pūhoi estuaries are managed for contact recreation with bathing being more common in the lower estuaries. Kayaking is a popular recreational activity in the Pūhoi estuary and also in the Mahurangi estuary and harbour. Other surface based recreational activities such as sailing and boating occur throughout the Mahurangi Harbour. Fishing and gathering of other food (e.g. shellfish) occurs throughout the Pūhoi Estuary and Mahurangi Harbours. Public access is provided to the Mahurangi estuary with a waterfront walkway in Warkworth

	town. Access to the shoreline is also possible in many other areas of the Mahurangi Harbour. The estuaries contain the Mahurangi and Wenderholm (in Pūhoi estuary) regional parks.

4.6 Existing infrastructure

There is limited downstream infrastructure that may be affected by the Project.

In the Mahurangi catchment there are bridges on Perry Road, Woodcocks Road, Falls Road, SH1 and Elizabeth Street, which are all remote from the report.

In the Pūhoi catchment there are existing SH1 culverts in the Pūhoi and Hungry Creek Sectors downstream of the indicative Project alignment. We have had these culverts surveyed and show them in the drawing set. Figure 9 below shows the location, diameter and ecological reference of these SH1 culverts, relative to the indicative alignment.

Water supply for Warkworth by Watercare and for aquaculture by Genesis is identified in Table 4.

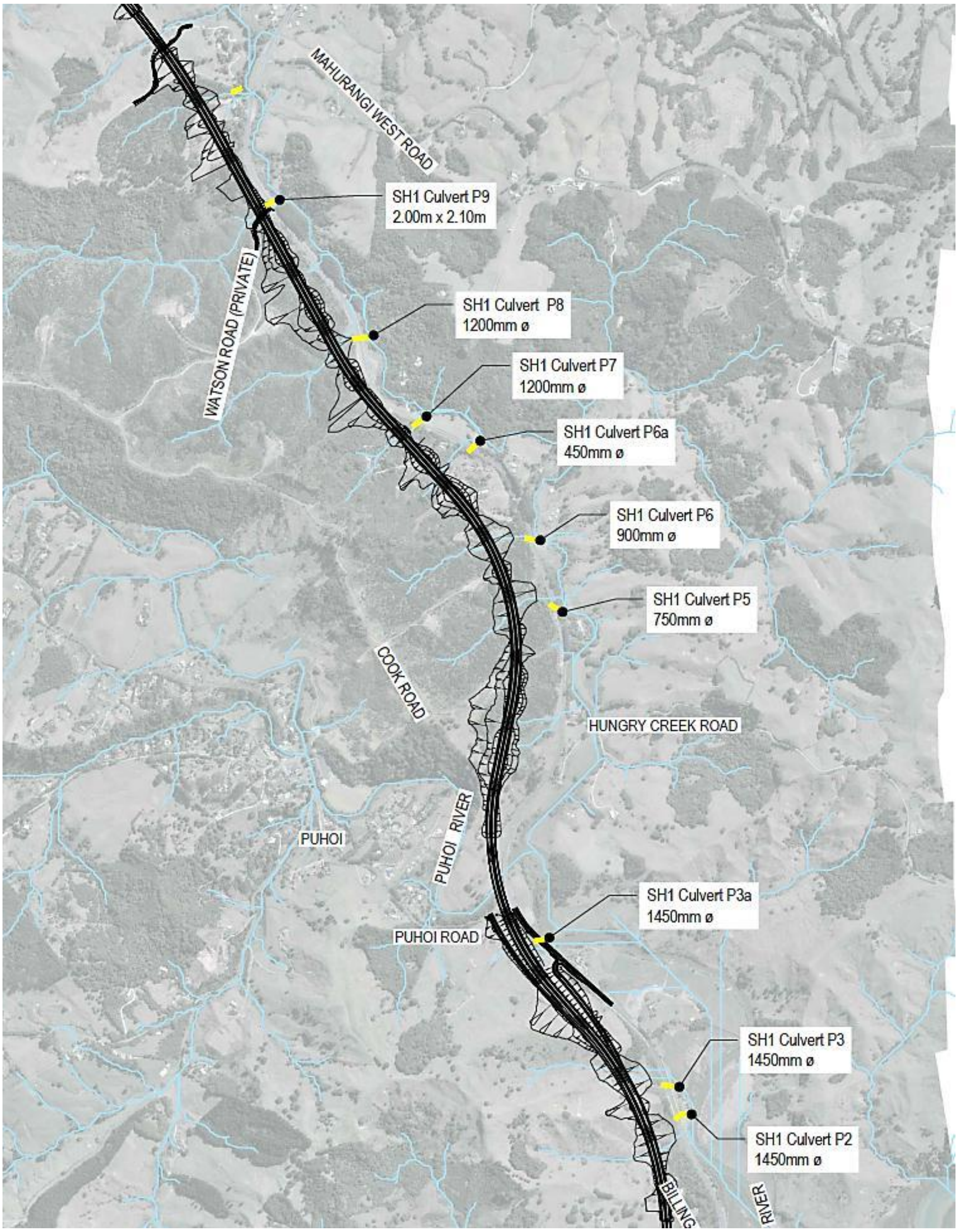

Figure 9: Existing State highway 1 culverts

5. Assessment criteria and considerations

The assessment matters establish the framework for our assessment of effects (Section 8). The assessment criteria and conditions have been developed from the RMA, ARP:ALW and Auckland District Plan: Operative Rodney Section. The key assessment criteria matters concern stormwater quantity, stormwater quality, human impacts, ecological impacts and flooding.

A number of water consents are held for activities in the Pūhoi and Mahurangi catchments. The current consents relevant to the potential effects of the Project are held by Watercare for the supply of the Warkworth water treatment plant and for 42 marine aquaculture activities. Also the NZTA hold a number of relevant consents for the NGTR, Hungry Creek passing lane and twin streams.

This section summarises the statutory and non-statutory context and develops the assessment matters used for our assessment of the operational water effects of the Project. The resulting assessment criteria and considerations are used as the framework for our assessment described in Section 8.

5.1 Statutory context

The key statutory documents applicable to the assessment of effects include the:

- Resource Management Act 1991 (RMA);
- National Policy Statement: Freshwater Management, 2011;
- National Environmental Standard for Sources of Human Drinking Water (2007);
- Auckland Council Regional Plan: Air, Land and Water Plan (ARP: ALW); and
- Auckland Council District Plan: Operative Rodney Section (District Plan).

The relevant statutory requirements that must be met are detailed in these documents. A full statutory assessment is included in the AEE.

5.2 Auckland Council Guidelines

Our operational water assessment relies on the following non-statutory Auckland Council guidelines from the (former) Auckland Regional Council (ARC) Technical Publication series:

- ARC Technical Publication 108: Guidelines for Stormwater Runoff Modelling in the Auckland Region (TP108);
- ARC Technical Publication Number 10: Stormwater Management Devices Design Guideline Manual (TP10);
- ARC Technical Report: 2010/003: Contaminant Load Model User's Manual;
- ARC Technical Report: 2010/004: Development of the Contaminant Load Model; and
- ARC Technical Report: 2009/084: Fish Passage in the Auckland Region – a synthesis of current research.

5.3 NZTA Policy, Standards and Guidelines

The NZTA has several guiding documents in relation to operational water systems:

- NZTA Stormwater Treatment Standard for State Highway Infrastructure (May 2010);
- NZTA Environmental Plan (2008), which has objectives for water resources as follows:
- W1 Ensure runoff from State Highways complies with RMA requirements;
- W2 Limit the adverse effects of run-off from State Highways on sensitive receiving environmental;
- W3 Ensure stormwater treatment devices on the network are effective;
- W4 Optimise the value of water management through partnerships with others; and
- NZTA Fish Passage Guidance for State Highways (March 2013).

5.4 Relevant current consents

There are 417 regional consents, including stormwater discharge consents, in the Mahurangi and Pūhoi catchments. The NZTA holds 66 of these consents for stormwater discharges, earthworks, coastal structures, reclamation, streamworks and bores

The consents relevant to the potential effects of discharges to water from the Project are as follows:

- A consent held by Watercare for the supply of the Warkworth water treatment plant from the Mahurangi River at Warkworth; and
- Resource consents for 42 marine aquaculture activities in the Mahurangi estuary. The locations of these consented activities are throughout the estuary as follows: Browns Bay (5), Cowans Bay (3), Dyers Creek (7), Huawai Bay (1), Mahurangi River (6), Nimaru Bay (1), Pukupuku Inlet (1) and Te Kapa River (18). The Marine Ecology Assessment Report provides further information regarding the nature and locations of these activities.

5.4.1 Surface water users

With the exception of the Watercare surface water abstraction on the Mahurangi River, there are no consented surface water abstractions on watercourses within the Pūhoi or Mahurangi catchments that could be affected by the Project. The only other two consented water takes in the wider area are for irrigation of horticulture crops and the takes are located on streams near Warkworth that are not affected by the Project.

The permitted surface water abstraction rule in the ARP: ALW allows for the taking and use of no more than 5m^3/day of water from a river, stream or spring, subject to conditions of consent. No information on permitted users is available from Auckland Council. We are aware of the Genesis Aquaculture Fish Farm on the M19 tributary of the Mahurangi. No water take consent exists for this site, however for the purposes of this assessment we have assumed surface water is taken as a permitted activity for the fish farm.

5.4.2 Network discharge consent

Consent Permit Number 22573 is a network discharge consent (NDC) for the Warkworth township that expired on 31 December 2012. The NDC is a resource consent that authorises the diversion and discharge of stormwater through the stormwater network and allows for upgrading of the network as appropriate. The conditions of consent are focussed on stormwater management in Warkworth township and are not relevant to the Project. We understand there is an Auckland Council application pending consent for a revised NDC for the Warkworth township (Morphum Environmental Ltd report, 28 September 2012).

5.4.3 NZTA consents

The NZTA consents that are relevant to the Project are:

- Consents for stormwater diversion and discharge for the NGTR, including the Johnstone's Hill tunnels and northern portal area, Titfords Bridge and the Turnaround area; and
- Consents for SH1 culverts that will be affected by the Project including the Hungry Creek Passing Lane (in Pūhoi catchment) and Twin Streams (in Mahurangi catchment).

The NZTA consents and their relevance to the Project are summarised in Table 6.

Table 6: Existing NZTA consents

Area		Consent No.	Consent Type	Date issued	Description	Relevance to Project
Hungry Creek Passing Lane		28817	Diversion & Discharge	2004/02/12	Divert and Discharge Stormwater to the Hikauae Stream in relation to construction of the Hungry Creek passing lane	Indicative alignment passes close to consent area. Ensure treatment devices are not impacted.
Hungry Creek Passing Lane		29840	Streamworks	2004/10/20	Construction of the southern realigned section of the Hungry Creek passing lane which involves culvert repair and culvert extension.	Indicative alignment has upstream culverts.
Hungry Creek Passing Lane		30663	Streamworks	2005/04/13	Streamworks associated with reinstatement of Hungry Creek Art School access and car park.	Indicative alignment has upstream culverts.
NGTR	Orewa to Titfords Bridge	22682	Stormwater Discharge	2000/08/18	To authorise the diversion and discharge of treated stormwater from the completed Transit New Zealand State Highway Realignment Albany to Pūhoi Sector B2 6.5km of motorway to Nukumea, Otanerua, Waiwera and Pūhoi river catchments and their associated estuaries.	Indicative alignment through consent area. Ensure treatment devices are not impacted. Design tie-in to Johnstone's Hill tunnels to maintain SW within conditions.
NGTR	Orewa to Titfords Bridge	25592	Streamworks	2001/12/10	Overlaps Consent No. 22681	See Consent No. 22681
NGTR	Orewa to Titfords Bridge	30065	Streamworks	2004/12/23	Overlaps Consent No. 25592	See Consent No. 25592
NGTR	Waiwera Estuary to Titfords Bridge	30067	Coastal Structure	2004/12/23	a) Construction of twin adjacent bridge structures over the coastal marine area of the Waiwera Estuary for the "Four Lane Design Alignment" and extension of the Titfords Bridge structure over the Pūhoi Estuary. b) Removal of indigenous vegetation from the Waiwera Estuary (CPA 2) Discharge of sediment into the Waiwera and Pūhoi estuaries during construction	Outside the Project area, but demonstrates consents for activity similar to the proposed Okahu Viaduct.
NGTR	Waiwera Estuary to Titfords Bridge	30068	Coastal Structure	2004/12/23	To authorise the occupation of part of the coastal marine area for a) The twinSH1 Waiwera Bridges; and b) The widened parts of Titfords Bridge.	See Consent No. 30067

Area		Consent No.	Consent Type	Date issued	Description	Relevance to Project
		30401	Coastal Structure	2005/07/01	Overlaps Consent No. 30067	See Consent No. 30067
		30402	Coastal Structure	2005/07/01	Overlaps Consent No. 30068	See Consent No. 30067
	Titfords Bridge	30397	Coastal Other	2005/07/01	To authorise the construction of a declamation, including the disturbance of the seabed and removal of vegetation, for the purpose of wideningSH1.	Titfords Bridge is downstream of proposed Okahu Viaduct
	Titfords Bridge	34443	Stormwater Discharge	2007/09/24	Discharge and diversion of stormwater from SH1 and the pedestrian walkway	See Consent No. 30399
	Titfords Bridge to Turn-Around Bay	30399	Stormwater Discharge	2005/07/01	For activities associated with the widening of Titford's Bridge and 780m of carriageway widening and a turnaround facility to the north of Titford's Bridge.	Indicative alignment passes close to consent area. Ensure treatment devices are not impacted.
	Johnstone's Hill tunnels	36431	Discharge Other	2008/12/19	To authorise the discharge of deluge water from a fire suppression system within the Johnstone's Hill motorway tunnels via stormwater ponds into the Waiwera and Pūhoi estuaries	Design tie-in at Johnstone's Hill tunnels to ensure discharge of deluge water for fire suppression system not impacted.
Twin Streams Culvert		29318	Streamworks	2004/06/23	To authorise approximately 8m of streambed disturbance associated with the extension of a culvert crossing. Extension of 'Twin Streams Culvert' to enable widening of SH1 to reduce the crash rate which currently exists under present conditions.	Unlikely to be of relevance due to distance from Indicative Alignment.

5.5 Summary of assessment matters

A summary of the assessment matters from the RMA, ARP: ALW and District Plan are included in Table 7. The key assessment matters concern stormwater quantity, stormwater quality, human impacts, ecological impacts and flooding. For each of the assessment matters, various criteria and considerations are listed that form the framework for our assessment of effects (refer Section 8). Common to the RMA and all plans is the requirement for options to be assessed and the BPO selected.

Table 7: Assessment criteria and considerations

Matter	Criteria/consideration
Best Practicable Option	
Best Practicable Option (BPO) approach	The ARP: ALW requires treatment of stormwater to be achieved via the selection of the BPO. In particular: • *Have regard to the applicant's reason for the proposed choice and any possible alternative methods of discharge, including discharge into any other receiving environment (RMA s105);* • *Incorporate low impact design principles;* • *Discharge water within the catchment from which it originates;* • *Consider Operation and Management Programmes; and* • *Consider the overall effects of stormwater discharges and diversion at the discharge points.*
Stormwater quantity	
Attenuation	The method of stormwater disposal shall minimise changes to the pre-development hydrological regime. In particular: • The peak flows for the 2 year and 10 year ARI rainfall event post– development events shall not be greater than the corresponding peak flows for pre-development events; • The volume of stormwater runoff for post-development events shall be minimised; and • The time of concentration for post-development events shall be maximised so that it is as close as practicable to the time of concentrations for pre-development events.
Bed / channel disturbance	Based on provisions of the RMA and relevant Plans, including the ARP: ALW, for streamworks: • *Stormwater disposal shall not cause downstream channel erosion; and* • *Measures shall be provided to avoid, remedy or mitigate significant adverse changes to a river / stream bed morphology and flow hydraulics.*
Erosion control at stormwater outfalls	All stormwater outfalls shall incorporate energy dissipation and/or erosion protection measures as required, minimising the occurrence of bed scour and bank erosion. The design of stormwater outfalls shall assess various rainfall events and tailwater levels (stream and sea levels) to ensure the critical storm event is considered in the design.
Overland flow	For major overland flow paths in excess of the capacity of the primary systems, secondary flow paths are provided and maintained to allow surplus stormwater from critical storms, up to the 100-year ARI rainfall event, to discharge with the minimum of nuisance and damage.

Stormwater quality	
Water quality treatment	Have regard to the nature of the discharge and the sensitivity of the receiving environment to adverse effects (RMA s105). In particular: • *Consider water treatment devices that will filter litter, floatables and silt particles;* • *Discharges to be treated to remove at least 75% of TSS loads on an average annual basis (ARP: ALW);* • *Appropriate management of run-off from land-uses with a high contaminant generation potential; and* • *Consider toxic, persistent or bioaccumulative contaminants that would be detrimental to the receiving environment and the selection of water treatment devices to remove contaminants.*
Aesthetics and odour	Referring to RMA section 107, after reasonable mixing the contaminant or water discharged shall not give rise to any of the following effects in the receiving waters: *(c) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;* *(d) any conspicuous change in the colour or visual clarity; and* *(e) any emission of objectionable odour.*
Sediment discharge	Avoid, remedy or mitigate permanent adverse effects on the surrounding environment from the deposit of sediment, including the effects on ecological values and physical processes within the river or stream, and the potential to cause or exacerbate erosion or deposition within river / stream or on adjacent land.
Human impacts	
Human health and Amenity	Referring to National Environment Standard for Sources of Human Drinking Water 2007 concerning the granting of water permit or discharge permit upstream of abstraction point where drinking water meets health quality criteria: • *a regional council must not grant a water permit or discharge permit for an activity that will occur upstream of an abstraction point where the drinking water concerned meets the health quality criteria if the activity is likely to:* *(a) introduce or increase the concentration of any determinands in the drinking water, so that, after existing treatment, it no longer meets the health quality criteria; or* *(b) introduce or increase the concentration of any aesthetic determinands in the drinking water so that, after existing treatment, it contains aesthetic determinands at values exceeding the guideline values.*
Water users	Referring to RMA section 107; if after reasonable mixing, the contaminant or water discharged (either by itself or in combination with the same, similar, or other contaminants or water), is likely to give rise to all or any of the following effects in the receiving waters: *(f) The rendering of freshwater unsuitable for consumption by farm animals.* Then minimise the effects on other water users.

Ecological effects	
Protection of aquatic ecosystems habitat	Referring to RMA Section 107; if after reasonable mixing, the contaminant or water discharged (either by itself or in combination with the same, similar, or other contaminants or water), is likely to give rise to all or any of the following effects in the receiving waters: *(g) significant adverse effects on aquatic life* Then avoid, remedy or mitigate and significant adverse changes to ecological habitat including: • *enabling the colonisation of a diverted river or stream by aquatic flora and fauna following the completion of stream diversion activities;* • *enabling the restoration or enhancement of wetlands, or areas of indigenous vegetation or the habitats of indigenous fauna in any river/stream; and* • *not resulting in the permanent loss of any habitat of a rare or endangered species.*
Effects of piping / culverting (habitat loss)	Avoid remedy or mitigate significant adverse changes to ecological habitat including enabling the colonisation of the diverted river or stream by aquatic flora and fauna following the completion of the diversion activities.
Fish passage	Avoid remedy or mitigate significant adverse changes to ecological habitat by maintaining the passage of fish and other aquatic organisms both up and down stream.
Flooding	
Flooding	Do not give rise to flooding of adjacent land or exacerbate existing flooding by: • not increasing downstream flows and thereby worsening flooding in downstream areas; • not causing flooding of a habitable floor level in any dwelling in a 100 year ARI storm; and • not occupying flood storage volume below the 100 year ARI flood level.

6. Methodology

The methodologies we applied for our consent design of the Project's operational water systems and for our assessment of effects included:

- Designing stormwater treatment devices based on Auckland Council Guideline TP10;
- Assessing stormwater quality aspects using the water quality datasets for the catchments, stormwater contaminant concentrations from motorway studies and the Auckland Council Contaminated Load Model;
- Designing and assessing stormwater quantity aspects based on the TP108 method and the XP-SWMM model;
- Designing and assessing of culverts using the TP108 method and HY-8 culvert model for culvert sizing, HEC14 for energy dissipation design and assessment of velocity changes, and TR 2009/084 for fish passage design; and
- Assessing flooding aspects from the motorway footprint using the Auckland Council rapid flood hazard model, which uses InfoWorks Integrated Catchment Modelling (ICM) software.

This section summarises the methodologies we applied for our design of the Project's operational water systems and for our assessment of the Project's operational water effects.

6.1 Design philosophy

The stormwater design philosophy for the operational water system proposed for the Project is detailed in Water Assessment Factual Report 6: Stormwater Design Philosophy Report. That report records the design objectives, principles and criteria we have used for the current phase of the Project and will be used to inform designers in future stages of the Project.

In summary, the objectives for the operational water systems are:

- To ensure the performance of the motorway to the NZTA standards; and
- To avoid, remedy or mitigate adverse environmental effects.

In summary, we have adopted the following design principles for the operational water systems:

- The design will provide a best practicable option (BPO) to avoid, remedy or mitigate adverse environmental effects, determined through a robust evaluation of options;
- The design will integrate the total operational water system (collection and conveyance network; treatment devices; culverts and diversions and consideration of the floodplain);
- The design will include full consideration of stormwater operational implications throughout the design life of the asset;
- The design will best practicably mimic the existing hydrologic regime and setting, to deliver outcomes that avoid, remedy or mitigate adverse environmental effects;
- The design will avoid or mitigate changes that might make the current flood issues in the catchment worse;

- The design will provide for habitats in stream diversions where they existed prior to the Project. The designs will restore streams and recreate habitats to replicate the natural state and habitats that existing prior to the Project; and
- The design will provide where possible for fish passage in culverts for all permanent streams with future upstream habitats, and for intermittent streams where there is potential for fish habitat upstream.

6.2 Hydrological assessment

We undertook a hydrological assessment to compare catchment runoff flow outputs for 2, 10 and 100 year ARI rainfall events for pre and post-development scenarios. From this assessment we were able to identify key areas of risk, provide mitigation measures in the Project design where necessary, and assess the residual effects.

6.2.1 Hydrological approach

Our approach to the hydrological analysis is to use an un-calibrated hydrological model based on the Auckland Council TP108 method using XP-SWMM software. This hydrological approach forms the basis for consent level design and our assessment of effects. Validation of this approach by comparison with observed flow records at the Mahurangi flow gauge suggest that flows predicted by the XP-SWMM model are much larger than observed (refer Section 6.4).

For consent level design, the hydrological approach produces flows that are conservative. For assessment of effects, the models are used to compare pre-development flows and velocities to post-development flows and velocities, where the relative difference indicates the effect. Therefore, we consider the hydrological approach suitable for the purpose of consent level design and our assessment of effects.

More detailed hydrological and hydraulic modelling will be necessary for detailed design and confirming that consent conditions are met. More detailed modelling will also allow for refinement of culvert sizes.

6.2.2 Rainfall

Rainfall data used to calculate the catchment runoff was derived from TP108 based on the maximum predicted 24 hour rainfall depths for each catchment. We compared the 24hr rainfall depths to the summary statistics for the Auckland Council Warkworth, Mahurangi and Orewa rain gauges, and the High Intensity Rainfall Design System (HIRDS) databases. We used the TP108 based rainfall depths for our assessment as they were higher than rainfall depths obtained from the rain gauge summary statistics and HIRDS databases.

Our hydrological assessment included an increase in rainfall intensity to allow for predicted climate change effects. Increased rainfall intensity is an important consideration because these changes are predicted to occur over the life of the Project's water infrastructure. Climate change changes to rainfall were estimated for 2120, which corresponds to 100 years after the Project completion.

We multiplied the TP108 rainfall data by the factor recommended in the Climate Change Effects and Impacts Assessment (Ministry for the Environment (MfE), 2008). Extreme rainfall events relative to 1990 were increased based on a mean predicted temperature rise for the Auckland region of 2.1°C to 2090. We then applied linear extrapolation of the 2040 and 2090 values in order to estimate the projected 2120 rainfall data.

The projected increase in maximum 24 hour rainfall depth for the 100 year ARI rainfall event in 2120 compared to TP108 values was 22.6%. The projected 2120 rainfall data for the Pūhoi and Mahurangi catchments that were used to estimate design flows and for the hydrological assessments are provided in Table 8. Full details about the rainfall data and climate change allowance are included in Water Assessment Factual Report 7: Hydrological Data Memo.

Table 8: Projected rainfall for 2120

ARI	Pūhoi (mm/24hr)	Mahurangi (mm/24hr)
2 year	129	146
10 year	224	247
100 year	343	380

6.2.3 Catchment analysis

We identified existing sub-catchments and land-uses within the Pūhoi and Mahurangi catchments using a combination of land-use maps, aerial images and 2m Light Detection and Ranging (LiDAR) contour information. We identified post-development catchments and land-uses by considering the geometric design of the Project and nominated spoil disposal sites within the designation. We visited the site a number of times to supplement our delineation of each catchment and enable land-uses to be identified more accurately.

6.2.4 Hydrology

The hydrology is based on the TP108 method which uses a US Department of Agriculture, Soil Conservation Service (SCS, 1986) guidelines approach. The TP108 method is considered appropriate and industry practice for the Auckland Region.

The SCS method uses a curve number (CN) to describe the runoff characteristics of the land with a higher CN resulting in greater runoff. The SCS guidelines suggest that the major factors determining the curve number are the hydrological soil group, surface cover type, soil treatment, hydrological condition, and antecedent ground condition (i.e. the soil moisture content prior to a rainfall event). We assessed that the Project area consisted of group C soils (mudstone/sandstone), which is consistent with the geology of the catchments (refer Section 4.2). The curve numbers assigned for the land-uses in the Project catchments are shown below in Table 9. Project areas modified by earthworks, such as fill embankments, cut slopes and spoil sites, are likely to generate higher runoff, and to reflect this higher anticipated runoff we assigned higher CN numbers to these areas.

Table 9: Curve numbers assigned for the Project

Land	CN
Forestry Area	70
Native Bush	70
Farmland/Pasture	74
Project fill embankments, vegetated cut slopes and spoil locations (>1.2:1 Slope)	79
Project motorway surface and rock cuts	98

6.2.5 Hydrological modelling

We used the XP Solution's Storm Water Management Model (XP-SWMM) software for our hydrological modelling.

The model has been applied as primarily a hydrological model. The runoff component of XP-SWMM operates on a collection of sub-catchment areas that generate stormwater runoff based on the TP108 method. The hydraulic modelling of stream channels is to convey water to the end of the catchment so that cumulative effects of the Project on the catchment can be assessed.

The hydraulic representation of stream channels is to link and convey flow, not for prediction of flood levels. The hydraulic representation of stream channels in the model is based on a small number of surveyed cross-sections. The stream channels remain the same for the pre and post-development models. The only changes between the pre and post-development models occur in sub-catchments that include the motorway, where the changes to land-use and drainage paths are simulated. Wetlands for water management are modelled as nodes with outflow equalling inflow (i.e. no volume for storage and attenuation).

We also included existing culverts on SH1 that were downstream and in close proximity to the indicative alignment (based on survey of diameter, upstream invert level and SH1 road level on the upstream side of the carriageway).

Models were run for 2, 10 and 100 year ARI rainfall events for pre and post-development scenarios. The modelling was divided into the two catchments – Pūhoi and Mahurangi. Specific locations were used for flow comparisons between pre and post-development situations, which were selected to give a representation of flow changes in tributaries and cumulative flow changes in the main streams.

The hydrological assessment is detailed in full in Water Assessment Factual Report 9: Hydrological Assessment Memo.

6.3 Flooding assessment

Our approach to assess flooding has been to work cooperatively with Auckland Council and its modelling team who are actively assessing the flood risk in the Warkworth region. Auckland Council has a rapid flood hazard model built using InfoWorks ICM software, which was supplied for our flood assessment. The advantage of using this model is a consistent approach to flood planning and assessment. The rapid flood hazard tool is a high level type model used to screen for flood hazard issues. Auckland Council is developing a more detailed flood model for Warkworth township, but this model will not be ready prior to the Project applications being lodged.

We undertook our own assessment of the Auckland Council rapid flood hazard models. Our assessment is detailed in full in Water Assessment Factual Report 10: Flood Assessment Memo. We consider the Auckland Council models to be of relevance and of sufficient accuracy for our assessment of the Project effects on flooding, as our assessments are based on comparisons between existing and post-development bi-functions of the relevant difference (the change). In our experience however, the models are often conservative and over-predict flows and water depth, which is why they are used as a rapid modelling approach to develop an understanding of flooding issues prior to development of more accurate models. We acknowledge that more detailed modelling and calibration of the model would more accurately define peak flood levels and recommend such a model be prepared as part of the Project’s detailed design.

We added the indicative alignment into the Council rapid flood hazard model to create a post-development scenario. Only the motorway alignment between and inclusive of the Woodcocks Road Bridge and the Carran Road Flood Relief Bridge was incorporated into the post-development scenario as these locations are the only parts of the motorway that potentially impact on the main floodplains. Inclusion of other aspects of the motorway alignment without the associated culverts would artificially detain runoff in these areas and distort the predicted flow rates in the lower Mahurangi River.

We ran the post-development scenario for a 100 year ARI rainfall event and included allowance for the effects of climate change. We compared the differences in floodplain extents and flood water levels between the pre and post-development situations. Our analysis of the potential effects of the indicative alignment on flooding is described in Section 8.6.

6.4 Model verification

We verified the Mahurangi XP-SWMM model against results from the rapid flood hazard modelling that Auckland Council had recently carried out (refer Section 6.3 for details). The Mahurangi XP-SWMM model predicted a peak flow of 577m^3/s for the 100 year ARI rainfall event downstream of Falls Road compared to the 585m^3/s predicted by the rapid flood hazard model. Both the XP-SWMM and rapid flood hazard models use the TP108 method for rainfall-runoff modelling. Neither the XP-SWMM nor the rapid flood hazard models are calibrated to observed data. The 100 year ARI flow estimated for the Mahurangi flow gauge, located slightly downstream at Mahurangi College, was 281m^3/s with 90% lower and upper confidence intervals of 191m^3/s and 414m^3/s respectively, based on 30.6 years of records.

Therefore we consider the XP-SWMM and rapid flood hazard models to be conservative. There are a number of reasons why the models are conservative which include:

- Simultaneous pattern of rainfall across the entire catchment, whereas, in reality rainfall tends to be more variable over large catchments. As a result the 100 year ARI rainfall event results in a flow larger than the 100 year ARI flow event;
- Floodplain storage is not properly accounted for with the XP-SWMM model. Floodplain storage is not represented well due to 1D architecture; and
- The rapid flood hazard model assumes that ponding areas are full at the time of the event.

We have not verified the Pūhoi XP-SWMM model as there are no other models or flow gauges to verify the model against. The model uses the same assumptions as the Mahurangi XP-SWMM model and is immediately adjacent to the Mahurangi catchment. We therefore expect the Pūhoi XP-SWMM model to also be conservative for the same reasons as the Mahurangi XP-SWMM model.

We consider a conservative and un-calibrated hydrological model to be appropriate for the assessment of effects. For design purposes, the conservative flow estimates give maximum flood extents and potentially larger than necessary culverts. For assessment of effects purposes, the model estimates the relative difference in flows between pre and post-development scenarios that results from changes to land-use and drainage paths and is therefore an appropriate tool for assessing effects. We recognise that the effects of the Project on flooding may reduce as a consequence of further investigation and refinement of the operational water system during subsequent design phases.

An assessment of the effects of the hydrological changes due to the Project throughout each catchment is provided in Section 8.

6.5 Stormwater reticulation

The stormwater reticulation has not been designed in this phase of the Project because it is not material to the consent applications. The stormwater reticulation is an engineering feature that is designed to convey stormwater from the Project carriageway and from the toe of cut (and fill) slopes to stormwater treatment devices. We only included stormwater reticulation in the cross-section drawings in order to adequately represent the Project area for assessment of effects and the designation requirements.

6.6 Stormwater treatment

All stormwater runoff from the new motorway will be treated prior to discharge. Stormwater quality treatment will be designed to remove at least 75% TSS on a long-term average basis in accordance with ARP: ALW requirements. We determined stormwater quantity management requirements by assessing the potential for erosion and downstream flooding using the TP108 method and XP-SWMM models that are described above in Section 6.2. This method is considered to be conservative (refer Section 6.4) and refinement of hydrological and hydraulic models are recommended at the detailed design phase.We selected stormwater treatment devices based on consideration of the BPO to prevent or minimise the effects on the environment. This BPO approach is based on the ARP: ALW requirement to minimise the effects of operational water management and stormwater discharges. The concept design of stormwater management devices is based on TP10.

The requirements for stormwater management devices are summarised in Section 3.1. The BPO assessment for stormwater treatment devices is described in Section 7.3. Operational stormwater treatment devices are shown on the drawings.

6.7 Cross drainage

6.7.1 Bridges

The hydraulic design requirements for bridges are that they accommodate conveyance of a 100 year ARI rainfall event with a minimum freeboard to the edge of the motorway of 600mm in non-forested areas and 1200mm in forested areas.

The Carran Road Flood Relief Bridge is the only bridge where waterway capacity requirements are the primary constraint and we therefore have undertaken preliminary hydraulic design. A concept design was developed using HY-8 (Federal Highway Administration, U.S.A.) culvert design software. We carried out further assessment using the rapid flood hazard model (refer Section 6.3 for details). The effect of the Woodcocks Road Viaduct on flooding was also assessed in the same flood hazard model. Flood conveyance and the afflux (rise in water level on the upstream side of the bridge) are key to our design and assessment and were therefore considered.

6.7.2 Culverts

The need for and the location of culverts were determined following the catchment analysis described in Section 6.2.3 using land-use maps, aerial images, 2m LiDAR contour information, and the nominated spoil 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 using the rainfall data described in Section 6.2.2.

The sizing of each culvert was determined using HY-8 culvert design software. The culvert sizes required for the alignment were based on a range of hydraulic requirements and additional considerations for safety and maintenance as detailed in Table 10.

Table 10: Culvert sizing criteria for the motorway

Criteria	Source
Hydraulic capacity: • Pass a 10 year ARI without heading up; • Minimum freeboard of 500mm during 100 year; ARI 500mm from edge of carriageway; and • Accommodate 100 year ARI with Headwater Depth ÷ Culvert Diameter < 2.	NZTA RoNS Standard, RDC Standard for Engineering Design (2009) Water Assessment Factual Report 6: Stormwater Design Philosophy Report (2013)

Criteria	Source
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).	Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo (2013)
Minimum diameter for safety and maintenance purposes: • Culvert < 30m length = Culvert to be 600mm minimum diameter; • Culvert 30 – 100m length = Culvert to be 1200mm minimum diameter; and • Culvert > 100m length = Culvert to be 1600mm minimum diameter.	Water Assessment Factual Report 6: Stormwater Design Philosophy Report (2013)
Minimum cover • Culverts shall be provided with not less than 600mm of cover.	NZTA RoNS Standard, Austroads Guide to Road Design part 5 Drainage Design

For culverts proposed for ancillary public roads (SH1, Moirs Hill Road and roads associated with underpasses), the hydraulic criteria will apply.

For culverts located in new private roads, we propose less onerous design criteria because the high level of performance necessary for a motorway is not warranted for a low usage and low speed private road. The culvert sizing criteria for new private roads (such as the property access road off Wyllie Road) are listed below:

- Culvert to pass 10 year ARI flows with heading up of less than 1000mm;
- Culvert to have a minimum depth of cover 600mm below road surface level; and
- Overland flow paths are to accommodate flows exceeding the 10 year ARI.

Field survey work was performed to establish the profile of three streams where we are proposing culverts to determine whether the LiDAR survey was sufficiently accurate for the consent design. These streams are located where culverts 58400, 57600 and 54700 are proposed. The data obtained from the field survey work allowed us to establish a more accurate culvert gradient. This gradient was similar to the LiDAR based design. This comparison between the LiDAR and survey data provided confidence in our LiDAR based design elsewhere.

Culvert details are shown in the drawing set.

Fish passage has been provided where required based on the Project's freshwater ecologist's assessment of effects (refer to the Freshwater Ecology Assessment Report). The BPO for mitigating the effects on fish passage is described in detail in Section 7.7.2. We developed a flow chart in conjunction with the Project's freshwater ecologist to determine the nature of the fish passage measure that is appropriate for each culvert type where fish passage is required (refer

Figure 12 in Section 7.7.2). In Section 8.5.3 the effect of fish baffles on flow conveyance is discussed.

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. The BPO for mitigating the effects of erosion at a culvert outlet is described in detail in Section 7.7.3. We developed the flow chart in Figure 13 in Section 7.7.3, which determines what energy dissipation structure was most suitable for each culvert based on fish passage, construction space available and the energy of the flow.

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 then designed the energy dissipation structure to minimise the velocity change at the outlet. Our assessment of the effects of the Project on erosion at stormwater outfalls is summarised in Section 8.2.3.

We 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 7.8.

The culvert design is detailed in full in Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo.

6.7.3 Overland flow paths

Our approach to assess the effect of the Project on overland flow paths has been to use outputs from the hydrological assessment described in Section 6.2 and the flooding assessment described in Section 6.3. Our sizing criterion for overland flow paths is that overland flow paths are to be provided and maintained for flows in excess of the primary drainage network capacity to accommodate flows up to and including the 100 year ARI rainfall event.

We identified overland flow paths during the catchment analysis and hydrological modelling described in Section 6.2. By using the outputs from the hydrological assessment, we are able to provide the Project with cross drainage sized for the 100 year ARI and located to ensure this design criterion is met.

An area of particular interest is the Carran Road sector where flooding is an existing issue in the lower Mahurangi catchment, including in parts of Warkworth. This flooding issue is discussed in Section 4.3. We used the rapid flood hazard modelling to identify the extent of the floodplains and major secondary flow paths for the Mahurangi River Left Branch that interact with the Project in the Carran Road Sector. These floodplains and major secondary flow paths are to be crossed by the alignment and the effects of these crossings are mitigated by measures discussed in 8.6.

All wetlands will be designed so that local overland flow will be diverted away from the wetland and, as noted in Section 3.1.3, each wetland is off-line. Additional clean water cut-off drains will be constructed above the alignment to prevent overland flow from entering the Project.

Our assessment of the effects of the Project on overland flow is described in Section 8.2.4.

6.8 Stream diversions

The principal objective for stream diversions is to recreate streams and habitats to replicate the natural state of the steams that exists prior to the Project. We developed a flow chart that selected the most suitable type of stream diversion based on fish passage criteria. The flow chart is shown in Section 7.9.

We developed stream diversion requirements to describe the outcomes for stream diversions, and these are discussed in more detail in Section 7.9. We developed three stream diversion typologies collaboratively with the Project's engineers and ecologists, with input provided from Hōkai Nuku.

The stream diversion design is detailed in full in Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo.

6.9 Water quality assessment

The assessment of the change in water quality associated with the Project focused on the predicted change in water borne TSS, Zn, Cu and Total Petroleum Hydrocarbon (TPH), which are the contaminants that are commonly associated with and used for assessing the effects of operational road runoff on water quality. Models (ARC 2010) and existing data (Moores 2009) exist for assessing the change in these contaminants associated with land-use change and our assessment methods are described in this section.

Stormwater management devices, while generally beneficial can cause an increase in temperature and increase in bacterial contaminants. We based our assessment of the effect of stormwater management devices on water quality, on our experience of similar projects elsewhere in New Zealand.

6.9.1 Contaminant Load Model

We used the Auckland Council Contaminant Load Model (CLM) to predict the change in contaminant load in the Pūhoi and Mahurangi catchments for the pre-development and post-development scenarios. The CLM provides an overview of the spatial changes in contaminants associated with the Project.

The former ARC developed the CLM for Auckland's urban catchments. The CLM user manual (ARC, 2010) recommends that when users apply the CLM to catchments where the urban proportion is less than 80%, then only urban land within the catchment should be modelled.

Both the Pūhoi and Mahurangi catchments have urban proportions less than 80% and therefore the model has focused on just the urban and impervious land within the catchments. The results from the model describe the relative change in contaminant load between the pre and post-development project scenarios, rather than estimate a change in absolute contaminant load.

The model accounts for the traffic predictions in 2031 in the "with" and "without" road scenarios, and the predicted land-use at 2031. The SATURN traffic model used for the traffic assessment was used to provide traffic inputs for the CLM. The traffic modelling for both the construction and operation phase of the Project is described in the Construction Traffic Assessment Report and the

Transportation and Traffic Assessment Report respectively. The vehicles per day at 2031 on the indicative Project alignment south of the Pūhoi ramps were assumed to be 22,800 VPD and 16,100 VPD north of the ramps. The water quality assessment has accounted for the level of stormwater treatment that is likely to be achieved by stormwater infrastructure that currently drains SH1 for the pre-development scenario. For the post-development scenario we assumed that all stormwater will be treated by constructed wetlands that are designed to meet TP10 design standards. We used the default contaminant removal rates for wetlands included in Auckland Council's CLM.

The relative change in contaminant load is a useful measure when comparing the pre-development and post-development scenarios to existing marine sediment quality data. However, the model does not provide results that can be compared with water quality guideline trigger values. Therefore, we used a second method to enable the comparison to Australian and New Zealand Environment Conservation Council (ANZECC) water quality guidelines, as described below.

6.9.2 Contaminant concentration method

The contaminant concentration method uses observed motorway water quality applied on a weighted catchment basis to estimate contaminant concentrations in receiving environments. Existing water quality data was used to estimate the existing concentrations of TSS, Zn, Cu and TPH in freshwater.

There are two sites within the Mahurangi catchment where Auckland Council has collected data since 2010. These sites are Mahurangi at Forestry Headquarters (FHQ) and at the Water Treatment Plant (WTP) at Warkworth. These data records are sufficiently long to provide a robust estimate of median water quality values at these sites.

To obtain existing water quality data for the MW site on the Mahurangi and the P10 and PL sites on the Hikauae Creek (refer Figure 8 for water quality monitoring sites), we collected four water quality samples in autumn 2013. The water quality monitoring programme is described in Water Assessment Factual Report 4: Water Quality Monitoring Report and results summarised in Section 4.4.

To determine the potential impact of the Project upon water quality, we used the median value for TSS, Zn, Cu and TPH from a combined data set to estimate the increase in TSS, zinc and copper as a result of the Project. The combined data set included road runoff data collected as part of NZTA research collected from all Auckland motorway sites monitored in the Moores et al (2009) study, and a single set of grab-samples collected in Autumn 2013 as part of this assessment from the existing SH1 between Pūhoi and Warkworth.

The contaminant concentration method enables the water quality in the existing situation to be compared to water quality guideline values, and for the predicted change in the water quality to be assessed against those guideline values. Our analysis of the effect of contaminants on water quality is described in Section 8.3.

Further detail on the CLM and the contaminant concentration method and results is provided in Water Assessment Factual Report 11: Motorway Runoff Report.

6.10 Assessment of effects

Our assessment of effects is described in Section 8. The criteria and considerations that form the basis of our assessment are identified in Table 7 in Section 5. These criteria and considerations are based on a review of the RMA, ARP: ALW and the District Plan. We consider and provide our assessment of effects for each criterion individually in Section 8. The magnitude of the impact is classified in accordance with Table 11 below.

Table 11: Criteria for describing magnitude of effects

Magnitude of Effect		Description
Significant	Very High	Total loss or very major alteration to key elements/features of the baseline conditions such that the post-development character/composition/attributes will be fundamentally changed and may be lost from the site altogether.
	High	Major loss or major alteration to key elements/features of the baseline (pre-development) conditions such that post-development character/composition/ attributes will be fundamentally changed.
Moderate		Loss or alteration to one or more key elements/features of the baseline conditions such that post-development character/composition/attributes of baseline will be partially changed.
Minor		Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible but underlying character/composition/attributes of baseline condition will be similar to pre-development circumstances/patterns.
Negligible		Very slight change from baseline condition. Change barely distinguishable, approximating to the “no change” situation.

7. Mitigation of effects by best practicable option

The Project includes mitigation measures within the operational water systems. For stormwater systems the best practicable option (BPO) approaches include:

- Stormwater treatment for all of the motorway and cut slopes by wetlands to remove sediment and contaminants from the runoff;
- Stormwater treatment for rock cuts with sediment traps for capture of additional sediment prior to wetlands; and
- Stormwater outfalls with erosion protection to minimise erosion.

For works associated with streams the BPO approaches include:

- Bridges for nine river / stream crossings;
- Fish passage measures at culverts where the freshwater ecologists identified freshwater habitats, with the exception of two culverts in the Carran Road sector;
- Energy dissipation at all culverts to minimise erosion;
- Stream diversions include ecological features to restore stream and riparian habitats where the freshwater ecologists identified freshwater habitats;
- A risk framework to assess the risk from debris flows and determine mitigation measures that include larger culverts and debris racks for culverts at high risk and relief inlets for culverts at moderate risk; and
- Alignment of the motorway to avoid the floodplain and minimise hydraulic effects where it is necessary to cross floodplains with bridges.

7.1 Introduction

This section of the report outlines the BPO assessment of mitigation measures included within the operational water management systems. These mitigation measures are incorporated into the Project to mitigate any potential adverse environmental effects associated with stormwater management and streamworks. This BPO assessment is intended to demonstrate that feasible solutions exist to meet both the Stormwater Design Philosophy (refer Section 6.1) and this report's assessment criteria/considerations (refer Section 5).

In this consenting phase, the Project is aiming to provide flexibility for designers and contractors in subsequent phases of the Project to provide alternative and innovative designs to meet or exceed the stormwater management objectives for the Project or to account for design changes that may result from design refinement. An example of a design change might be that during the detailed design phase of the Project, an alternative location and treatment technology for stormwater might be identified. An alternative design can be applied if it satisfies any resource consent conditions imposed.

This section gives reasons for the mitigation measures proposed as part of the Project. Section 8 assesses the residual effects on the environment after inclusion of these mitigation measures.

7.2 Stormwater treatment requirements

7.2.1 Best practicable option

The ARP: ALW requires the BPO be implemented with respect to minimising the effects of stormwater discharges. Section 2 (1) of the RMA (1991) similarly defines the BPO as:

> *"Best Practicable Option means the best method for preventing or minimising the adverse effects on the environment having regard, among other things, to:*
>
> *1) the nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects;*
>
> *2) the financial implications, and the effects on the environment, of that option compared with other options;*
>
> *3) the current state of technical knowledge and the likelihood that the option can be successfully applied."*

We selected the proposed stormwater treatment devices and designed them to concept level based on TP10 guidelines to meet the requirements of the ARP: ALW.

7.2.2 Stormwater treatment device requirements

Stormwater treatment devices provide for both water quality and water quantity treatment. The requirements for water quality and water quantity treatment are listed in Section 3.1.

7.2.3 Stormwater reticulation

Stormwater reticulation has not been designed for this phase of the Project because it is not material to the consent applications. Stormwater reticulation conveys stormwater from the Project carriageway and from the toe of cut (and fill) slopes to stormwater treatment devices. We only included stormwater reticulation in the cross-section drawings in order to adequately model the designation footprint required by the Project. Stormwater reticulation includes the following types:

- Kerb/channel/catchpit/pipe;
- Drainage channels/swales;
- Rock trap drainage channels; and
- Let down structures (i.e. inlets and outlets from wetlands, from motorway and/or streams).

There are opportunities for additional treatment devices, such as swales and catchpit sumps, to be incorporated into the stormwater reticulation to increase the stormwater treatment as well as provide conveyance. These devices are however not relied on for our assessment.

7.3 Stormwater treatment options

The BPO approach was used to determine the most appropriate stormwater treatment devices based on the options in TP10. In this section a brief description of the merits of different treatment devices which inform the choice of the BPO is provided. Site factors affecting the choice of BPO are also highlighted where relevant. To understand the operation and maintenance requirements of different devices and to inform our assessment, we sought feedback from Peter Mitchell of the Auckland Motorway Alliance (AMA). In this section, maintenance issues are highlighted where relevant. TP10 Chapter 4, and in particular Tables 4-8 and 4-9, summarises the effectiveness of various treatment devices in removing contaminants and attenuating peak flows.

Our BPO assessment determined constructed wetlands are the preferred stormwater treatment devices, due in particular to the overall water quality treatment achieved. Wetlands are described in more detail below together with the description, benefits, performance and ecological impact of other treatment devices we considered as part of the BPO process.

7.3.1 Swales

Engineered swales are effective devices for water quality treatment, however do not provide any water quantity control and are not suitable.

Swales convey runoff and provide treatment and can therefore reduce the costs associated with piping runoff over the same distance. Swales could form part of the longitudinal drainage system associated with the motorway. As the stormwater reticulation has not been designed in this phase, the potential benefits from swales are not included in our assessment.

Swales are not the BPO for any areas of the Project.

7.3.2 Grassed filter strips

Grassed filter strips are uniformly graded and densely vegetated strips of grass designed to treat stormwater runoff by filtration, infiltration, adsorption and biological uptake. Filter strips accept distributed or sheet flow and convey the runoff laterally from the roadside, meaning that runoff from the catchment is not collected and discharged at one point. The potential for erosion and scour due to the discharge is therefore reduced. Grassed filter strips provide the following benefits (ARC TP10):

- Effective at TSS concentration reduction (>80% removal);
- Effective at removal of Cu (typically 60%), Pb (typically 90%) and Zn (typically 80%);
- Can be used for vehicle recovery and sight lines;
- Aesthetically pleasing and incorporate low impact design principles;
- Low hydraulic head loss; and

- Eliminate need for capture and conveyance drainage network.

The main disadvantage of using filter strips on the Project is the large area required for the device at the side of the motorway. Therefore, they are not suitable for areas with moderate to steep slopes where additional earthworks would be required to accommodate the filter strips. Grassed filter strips do not provide any water quantity control.

Grassed filters are not the BPO for any areas of the Project.

7.3.3 Rain gardens

Rain gardens treat stormwater runoff by passing the water through a filter medium containing an organic component (a process called biodetection). The uniformly graded soil medium planting area and vegetated strip are designed to treat stormwater runoff by filtration, infiltration, adsorption and biological uptake. Rain gardens accept distributed or sheet flow and convey the runoff laterally from the roadside, collect the surface water in an extended detention zone, and through infiltration discharge it to a subsurface drainage layer. Rain gardens discharge flow over a relatively large area, and therefore the potential of erosion and scour due to the discharge is reduced. To retain the filter media within the rain garden and aid drainage, one or more layers of filter medium are used at the bottom of the filter. The raingarden surface can be planted with a range of vegetation.

One of the advantages of rain gardens over other treatment devices is that piped reticulation and outfall structures may not be required. Rain gardens provide similar benefits as described above for grassed filter strips (ARC TP10).

The disadvantages of using rain gardens on the new motorway are the same as those stated above for grassed filter strips. A large area is required for the device at the side of the motorway. A further disadvantage is the high maintenance cost. Rain gardens do not provide any water quantity control.

Advice from Peter Mitchell of AMA was that filtration/infiltration type stormwater assets are not desirable for Auckland motorways because of the rate of clogging due to the large sediment load. Due to clogging, the risk of surface flooding of the motorway increases and the effectiveness of treatment decreases (pers. comms. Peter Mitchell, Auckland Motorway Alliance. 27/03/2013).

Rain gardens are not the BPO for any areas of the Project.

7.3.4 Proprietary filter cartridges

Cartridge filters such as the Stormwater 360 StormFilter are (former) ARC approved for water quality treatment for high traffic load applications. The filter medium used in the cartridges for highway applications is a porous material that removes particles through direct filtration and absorbs oil and grease via capillary action. They also remove hydrocarbons via adsorption. These cartridges result in discharge stormwater quality that has been approved by the ARC to meet TP10 Guideline requirements of 75% removal of TSS. A benefit of using StormFilters to treat runoff from motorway catchments is the targeted removal of metals and hydrocarbons.

Cartridge filters are used for water quality treatment only and are not suitable when attenuation is required. Cartridge filters have a high maintenance requirement, due to the cartridges needing regular replacement. An advantage of cartridge filters over other devices is the small space required for the device.

Proprietary filter cartridges are not the BPO for any areas of the Project because of our requirements for extended detention.

7.3.5 Sand filters

Sand filters are similar to proprietary cartridge filters. They are most commonly used in industrial applications. Our experience suggests that the head loss requirement through sand filters is larger than that through the proprietary filter devices. Sand filters require a large physical space and more space for maintenance activities. Sand filters do not provide any water quantity control.

Sand filters are not the BPO for any areas of the Project.

7.3.6 Dry / wet stormwater management ponds

Stormwater management ponds are typically un-vegetated ponds that provide both water quality treatment and water quantity control, and are therefore a viable option for the Project. However, wetlands (discussed below) provide superior water quality treatment compared to ponds due to the benefits of vegetation within the wetland. Wetlands also provide greater visual amenity and a better habitat for wildlife.

Ponds are not the BPO for any areas of the Project.

7.3.7 Constructed wetlands

Wetlands and stormwater management ponds are the only treatment devices that provide water quantity control in addition to water quality treatment. Therefore they are the only options available (at present) in situations where water quantity treatment is required.

Constructed wetlands perform well as treatment devices by removing a range of contaminants. Advantages over ponds include increased filtering and biological treatment performance. Treatment features of wetlands include (ARC TP10):

- Settling of TSS;
- Uptake by wetland plants of nutrients and soluble metals;
- Filtering and absorption by wetland plants;
- Organic bottom sediments provide nitrification / dentrification (transformation and loss of nitrogen); and
- Evaporation of (volatile) petroleum compounds.

Wetlands manage temperature increases better than ponds, mainly because the vegetation protects the water from light penetration. Temperature affects the ability of water to hold oxygen, (as temperature increases oxygen levels decrease). These temperature changes can provide direct stresses on aquatic species and also make nutrients in sediments more susceptible to algal growth.

Compared to other treatment devices listed above, wetlands incorporate low impact design principles, have low maintenance requirements, low whole-of–life costs, greater visual amenity and are a better habitat for wildlife.

Constructed wetlands do not perform well where there is a high incoming sediment load. We include forebays in our assessment for the Project as they are likely to remove the coarser fraction of the total sediment load.

Constructed wetlands for the motorway will be densely planted to maximise the treatment effectiveness. Figure 10 shows a typical wetland section with indicative wetland and riparian planting. A banded bathymetry (i.e. staggered series of depths) will be used to increase the wetland vegetation as shown, and planting will be in accordance with Auckland Council and NZTA standards.

Constructed wetlands have many benefits over other treatment devices making them our BPO for this Project.

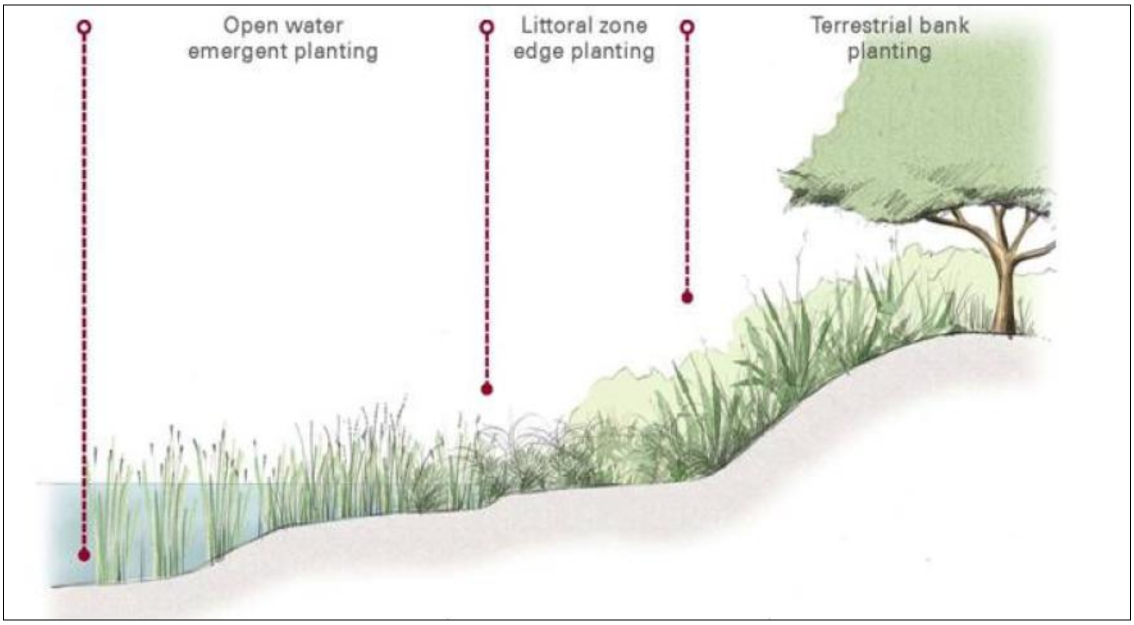

Figure 10: Typical wetland section

7.3.8 Sediment traps

Sediment traps are proposed for the Project in drains at the base of rock cut faces. These sediment traps are bespoke treatment devices that will capture sediment generated from rock cuts. On the NGTR project, cut faces have yielded larger sediment loads than anticipated over the initial years since opening (2009). The sediment has built up within rock lined swales that have proved challenging to maintain i.e. the rock lined swales are not easily cleared of sediment. Sediment has also accumulated in the rock fall zones at Chin Hill, which is shown in Photo 1.

Photo 1: NGTR sediment yield at base of rock cut

The proposed sediment traps collect sediment close to the source and protect the downstream wetlands from excess sediment. Maintenance will be required, especially during the early years of operation, to remove accumulated sediment and rock fall from the sediment traps. A typical detail for a sediment trap is shown on Drawing SW-307.

Information from Peter Mitchell of the AMA indicated that in late 2012 the NGTR maintenance team removed 405m^3 of sediment from the drain at the base of Chin Hill, which has a plan surface area of 13,300m^2. We were able to use this sediment generation information to estimate the sediment yield per year per m^2 of rock cut surface area for the NGTR. The indicative alignment for the Project passes through similar geological terrain therefore our calculated sediment yield rate for the NGTR is likely to be similar for the Project. From our sediment yield calculation, we have developed an initial baffle spacing table (refer Drawing SW-202) that can be tailored to suit a range of rock cut heights and longitudinal slopes at the base of the rock cuts. We developed our baffle design and associated spacing requirements in collaboration with the Project's geotechnical team who have concurrently designed concept rock traps at the base of the rock cuts to capture falling rock, mitigating the risk of them reaching the motorway. The sediment traps do not compromise the function and performance of the rock traps.

Sediment traps are proposed as the BPO to manage sediment generated from rock cut faces. They will be used in conjunction with the downstream wetlands for the treatment of stormwater runoff from the motorway and associated rock cuts.

Our calculations and methodology for the design of the sediment traps are described in detail in Water Assessment Factual Report 8: Cross Drainage and Stream Diversion Design Memo.

7.3.9 Vegetated roadside drains

Research carried out in the Auckland Region by the National Institute of Water and Atmosphere (NIWA) for NZTA show that vegetated roadside drains are effective at TSS removal. The research shows that the drains offer similar contaminant load capture to that of vegetated swales, achieving high removal rates of particulate and total copper and zinc.

Rural highways tend not to have a kerb and channel stormwater system and instead incorporate vegetated roadside drains. These drainage channels are generally "U" shape in profile and quite deep. This is an advantage over swales as swales require flatter side slopes making their overall footprint larger. The use of vegetated roadside drains reduces the footprint of the Project, which is particularly helpful where the Project is upgrading an existing ancillary road e.g. Moirs Hill Road, where available space is a constraint. Because of the low traffic volume expected to use these ancillary roads, we do not consider it necessary for these drains to discharge to wetlands for treatment or to have TP10 compliant treatment.

Whilst vegetated roadside drains are not specifically designed to provide treatment, their contaminant retention qualities make them the BPO for low traffic volume ancillary roads constructed or upgraded as part of the Project. The vegetation selected during the detailed design phase will provide water quality benefits through filtration and infiltration.

The detailed design phase will also consider the hydraulic sizing of the vegetated roadside drains to ensure that any risk of overtopping the road surface is mitigated.

7.4 Wetland locations

7.4.1 Rationale

We have proposed wetland locations as part of this assessment of effects in order to confirm the Project designation boundaries, and the wetland feasibility which is discussed in Section 7.4.2.

Our rationale for the location of the wetlands is as follows:

- Located to suit low points in the vertical alignment of the motorway;
- Efficiently spaced to ensure consistent sizing and catchment sizes;
- Located close to the indicative alignment in order to minimise the overall Project footprint. We use some of the landscape fill and spoil disposal areas 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;
- 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.

7.4.2 Feasibility

The indicative alignment for the Project is through similar geological terrain to the NGTR where a number of wetlands have been constructed. We recently visited the NGTR with Peter Mitchell of the AMA and looked at the location of selected wetlands. The NGTR wetlands are in a variety of sites including:

- Fill and spoil locations (Photo 2);
- Within cuts (Photo 3);
- Over stormwater culverts (Photo 4); and
- Existing flat ground where available (Photo 5).

Photo 2 shows the Nukumea Wetland on the NGTR which is located in a fill area.

Photo 2: NGTR Nukumea Wetland

Photo 3 shows the Otanerua Wetland on the NGTR which is located in a cut area.

Photo 3: NGTR Otanerua Wetland

Photo 4 shows the Middle Stream Wetland on the NGTR which is located over the Middle Stream culvert.

Photo 4: NGTR Middle Stream Wetland

Photo 5 shows the Waiwera Wetland on the NGTR which is located on existing flat ground.

Photo 5: NGTR Waiwera Wetland

Our experience gained from the design and operation of the NGTR supports the feasibility of the wetlands we propose for the Project, in particular the hill country areas. We have not modelled the earthworks associated with the proposed wetlands and associated cut and fill as we consider this is best done at the detailed design phase. Our experience from the design phase for the NGTR is that the wetland locations will be developed and refined once further site investigation and design is carried out. The majority of the NGTR treatment devices were optimised during design and moved from their specimen design locations. Our NGTR experience supports the feasibility of the proposed wetlands for the Project.

An observation from the NGTR visit was that while some wetlands have healthy vegetation, some wetlands have sparser planting. We recommend a consent condition for the Project requiring establishment of healthy wetland plants. Consideration should also be given to riparian plants especially on northern aspects that would increase the shading of the wetlands.

Our assessment of the effects of the wetlands proposed for the Project is described in Section 8.

7.5 Erosion control for stormwater systems

Stormwater systems need to perform reliably and minimise the generation of additional sediment.

7.5.1 Clear water cut-off drains

Clear water cut-off drains are proposed at the top of all cut faces where flow from above would otherwise flow over the downstream cut face. These drains will reduce erosion on cut faces by interception of (clean water) flow. Cut-off drains have the potential to erode so there will be a requirement to minimise erosion in these drains as part of the detailed design process.

7.5.2 Cut and fill faces

Cut and fill faces (batters) are required as part of the Project and rainfall and runoff have the potential to erode new sediment from the batters and transport that sediment downstream. The likelihood of this scenario is higher in the early stage of the operation phase of the Project when vegetation is establishing. The Construction Water Assessment Report deals with sediment (generation and capture) during the construction phase of the Project and has adopted a range of measures to limit impacts during construction.

The potential for erosion of cut and fill faces post-construction will remain throughout the life of the Project. This sediment generation can be seen in the NGTR section of SH1 immediately south of the Project. The Project proposes measures to limit generation or to control the sediment load, including:

- Vegetation cover on cut and fill slopes to minimise generation of new sediment; and
- Capture and treatment of runoff from cut slopes using;
  - Wetlands downstream of cut and motorway areas (refer Section 7.3.7); and
  - Sediment traps (refer Section 7.3.8).

7.5.3 Wetland outfalls

Wetland outfalls will be sized to convey the 100 year ARI flow rate. These flows will be piped to the adjacent stream.

In many instances, the flow can be directed to the inlet or outlet adjacent culvert and thus eliminate the need for duplication of energy dissipation devices.

Wetland outfalls will incorporate erosion protection measures to minimise bed scour and bank erosion in the receiving waterway. Typically this protection will be through an energy dissipation device and/or rock aprons. These erosion protection solutions are regarded by the industry as best practice and we consider they are a matter to be addressed in the detailed design phase. We consider the need to include such devices should be a requirement of resource consent conditions.

7.6 Bridges

The motorway alignment has numerous stream crossings. The options for the stream crossings are to provide a bridge or culvert, or to divert the stream to another culvert. Bridges impose the least environmental impact, but are more costly. Culverts have more environment impacts yet are more cost effective. Furthermore, the fill associated with culverts is often required to balance the volumes of earthworks required for cuts through ridges that are necessary to achieve an appropriate vertical alignment for the motorway.

Considerations for the choice of a bridge or culvert include:

- Vertical geometry of the road;
- Height and length of the crossing;
- Magnitude of the stream flows and width of the floodplain;
- Constructability of bridge or culvert;
- Other requirements for a bridge such as secondary roads or stock access; and
- Environmental considerations such as effects on aquatic and riparian ecology.

Bridges are proposed as the BPO for seven stream crossing locations. These locations and the key considerations are listed in Table 12. The locations and sub-catchments associated with bridges are shown in Figure 11.

Table 12: BPO assessment for bridges (including overall design considerations)

Bridge name	Consideration
Okahu Viaduct	• Estuary crossing • Moderate catchment (331 ha) • Desire to avoid reclamations (in the CMA) and effects on estuary • Combined crossing of Billing Road Driveway • Height and length crossing (vertical grade from Johnstone's Hill tunnels) • Prestressed concrete box girder has 75m spans which reduce the piers and construction activity in water • Reduced impact on Te Pā o Te Hēmara Tauhia at the southern abutment
Pūhoi Viaduct	• Significant river crossing (3,312 ha catchment, so design flow too high for culvert) • Desire to avoid reclamations • Major road crossing (Pūhoi Road) • Height and length of crossing • Good crane access available from flat terrain, concrete box girder gantry launching not required
Hikauae Viaduct	• Minor creek crossing (22 ha) • Hikauae Access Track required • Geotechnical conditions make embankment unsuitable
Schedewys Viaduct	• Major river crossing (527 ha) • Height and length of crossing • Geotechnical conditions make embankment unsuitable • Prestressed concrete box girder has 75 m spans reduced piers in rolling terrain • Overhead launching gantry avoids the need for specialised cranes for 39 m high beam lift.
Perry Road Viaduct	• Major river crossing (548 ha) • Height and length of crossing • Height and length crossing geotechnical conditions make embankment unsuitable • Overhead launching gantry avoids the need for specialised cranes for 40m high beam lift.
Kauri Eco Viaduct	• Major river crossing (190 ha) • Height and length of crossing • Kauri natural forest in area
Wyllie Road Overpass	• Passing over local road • Economic 13m span

Bridge name	Consideration
Woodcocks Road Viaduct	• Major river crossing (399 ha) and floodplain – Mahurangi River Left Branch • Road crossing • Sight lines at Woodcocks Road / Carran Road
Carran Road Flood Relief Bridge	• Major secondary flow path • Stock access incorporated
Minor Bridge – Property Access Road	• Stream crossing • Natural bush area conserved by minor bridge structure

Where possible, bridge piers are positioned outside of watercourses to:

- Reduce impacts of working within a water course during construction;
- Reduce potential scour of the riverbed; and
- Minimise the need for structures (abutments and piers) being located within the CMA.

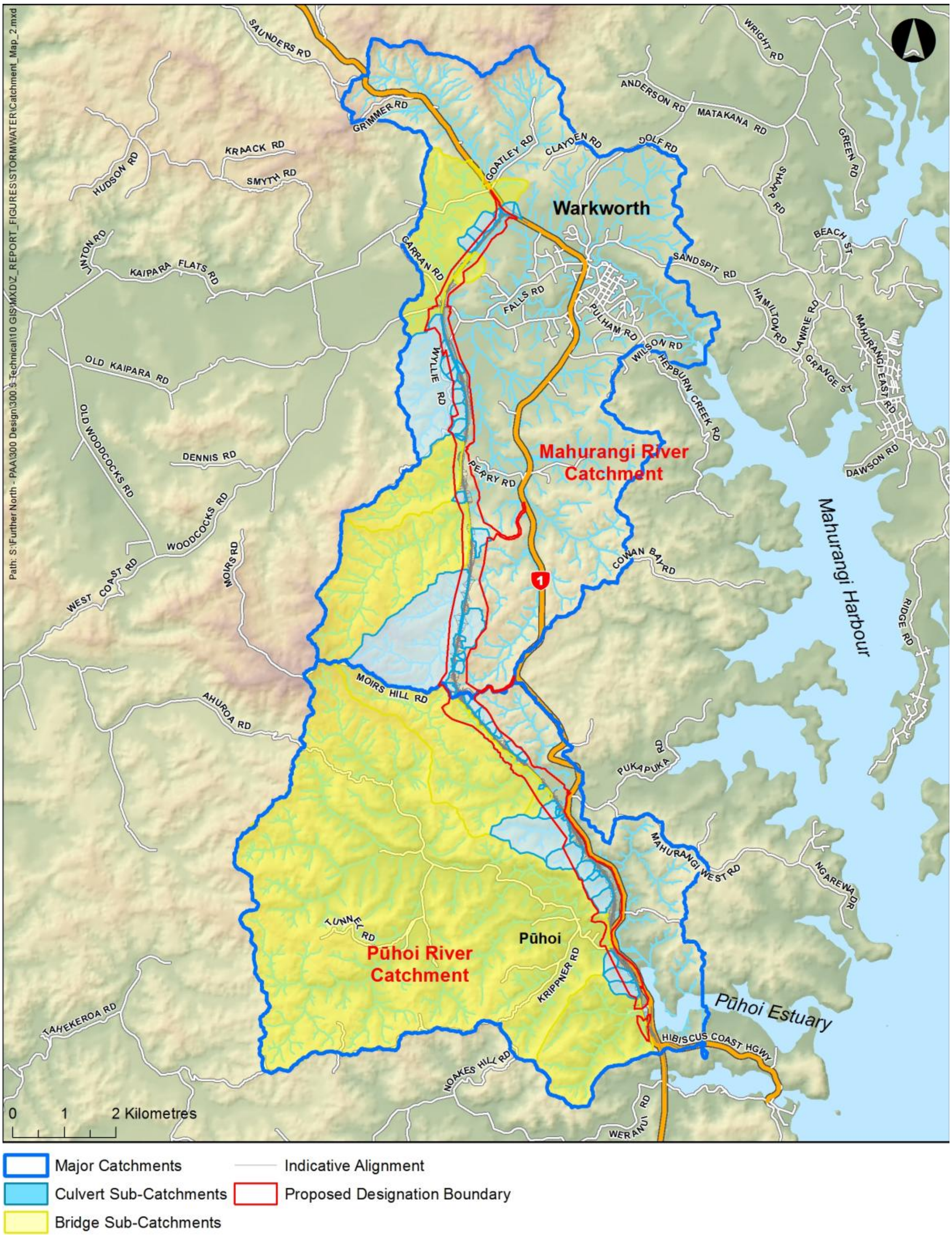

Figure 11: Culvert and bridge sub-catchments

7.7 Culverts

Culverts are proposed for 40 stream crossings. As noted above, embankments and the associated culverts facilitate balancing of cut and fill volumes for the Project.

Culverts are the BPO when the following conditions can be met:

- Culverts have sufficient capacity for the design flows and satisfy the sizing criteria in Table 10 in Section 6.7.2;
- Flooding effects from predicted afflux (rise in water level on the upstream side of a bridge/culvert) are acceptable;
- Environmental requirements such as fish passage, erosion control and energy dissipation are met; and
- Debris and sediment transport is managed.

We designed the horizontal and vertical alignments of the culverts to limit the culverts' environmental impact. The following sections describe the types of culverts, fish passage required, energy dissipation structures and erosion control measures at the outlets.

The sub-catchments associated with the culverts are shown in Figure 11.

7.7.1 Culvert types

In general the culverts will be concrete pipes. This type of culvert is the most cost effective type of cross drainage because concrete pipes are economical to produce and meet strength and durability requirements. The culvert diameters are based on either the larger of the hydraulic requirements or minimum requirements for maintenance access. The basis for our culvert design, including their diameters, is detailed in Section 6.7.2. Please refer to Drawing SW-201 for a typical culvert longitudinal section.

Larger concrete arch culverts 49500, 54700 and 60200 are proposed for three crossings of main tributaries to Mahurangi River and Hikauae Creek because the design flows are too large for concrete pipe culverts.

Special features of the concrete arch culverts include:

- Arch to achieve sufficient cross-section areas to meet the flow capacity,debris mitigation and access requirements;
- Concrete required for highest fills (however corrugated steel may be a suitable alternative for lesser fill heights, which will be determined at the detailed design stage);
- Racks upstream of the arch entrance to mitigate the risk of blockage by intercepting logs and other debris;
- Natural bed for fish passage; and
- Maintenance access through the culvert.

7.7.2 Fish passage

The Project's freshwater ecologists identified the permanent and intermittent streams within the Project area, as documented and named in the Freshwater Ecology Assessment Report. With the exception of only two streams in the northern valley area of the indicative alignment, fish passage has been provided at culverts for all permanent streams with upstream habitats, and for intermittent streams where there is potential for fish habitat upstream.

As part of our BPO design approach, we have considered the type of fish passage for each culvert based on the characteristic of the site and the type of fish passage required. Our flow chart for determining fish passage requirements is shown in Figure 12.

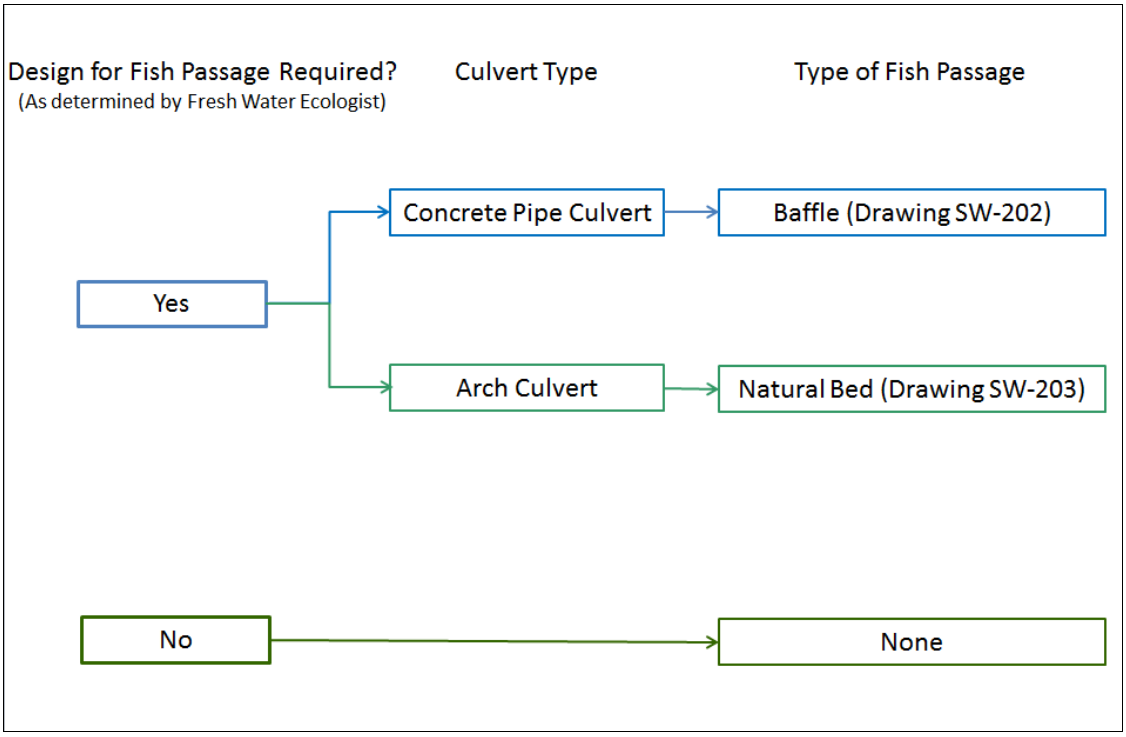

Figure 12: Flow chart for fish passage

The types of fish passage we propose are described below.

(a) Baffle type fish passage

The baffle design is based on Auckland Regional Council Technical Report Number 84, June 2009 (Fish Passage in the Auckland Region – a synthesis of current research). Plastic rectangular baffles create low velocity zones allowing fish to rest as they move through the culvert. These baffles are successfully used for fish passage in concrete pipe culverts for the adjacent NGTR section of SH1.

We propose a baffle type fish passage for concrete pipe culverts where both swimming and climbing fish species are expected. Refer to Drawing SW-202 for typical details.

Fish passage baffles can introduce additional turbulence and obstruction to flow within a culvert. The baffles also increase the effective roughness of the culvert barrel, in some cases to the detriment of a culvert's hydraulic efficiency and flow capacity.

Research carried out by Leong et al (2007) on selected NGTR culverts show that in some cases the roughness of the culvert wall with fish passage baffles in comparison to a plain concrete pipe barrel can double. This research is referenced in an American Society of Civil Engineers (ASCE) paper which investigates the influence of fish passage baffles on flow within culverts (Feurich et al, 2007). The findings from both papers conclude that although the installation of baffles does improve fish passage, it can increase water depth and decrease velocity of flow. As a consequence the flow capacity of the culverts can decrease, especially if the hydraulics are outlet controlled.

In practice, for the NGTR and similarly for the Project culverts we propose, culvert flow capacity is generally governed by inlet control conditions and rarely by the capacity of the culvert. Thus the effect of fish baffles on the effective culvert flow capacity may be limited. Inlet control of a culvert is when a culvert barrel is capable of conveying more flow than the inlet will accept. Hydraulic characteristics downstream of the inlet control section do not affect the culvert capacity. Also the minimum size of many Project culverts is governed by access arrangements (refer Table 10) and they are larger than required for hydraulic capacity.

There may be instances in the Project where detailed design establishes that a culvert is outlet controlled and baffles are required for fish passage. Outlet control of flow occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept. This outlet control component in a culvert is either located at the culvert outlet or is further downstream and may be in the form of an obstruction in the downstream channel or hydraulic resistance of the stream channel. Further investigation and analysis during the detailed design phase of the Project will confirm the fish passage requirements and culvert sizes.

A culvert may need to increase in size from that specified in Table 3 in Section 3.4.

Photo 6 shows a baffle type fish passage arrangement installed at the NGTR.

Photo 6: Baffle type fish passage installed at NGTR culvert.

(b) Natural bed type fish passage

The natural bed type of fish passage replicates a natural stream bed by using raised baffles at intervals to hold sediment within the bed of the culvert. The alternating baffle openings and sediment basins create a low flow channel with low velocity zones to encourage fish passage through the culvert.

We propose a natural bed type of fish passage in arch culverts where both swimming and climbing fish species are expected (Culverts 49500, 52100 and 54700). Refer to Drawing SW-203 for typical details.

Table 3 in Section 3.4 identifies the culverts where we are providing fish passage, and the type of fish passage we propose.

7.7.3 Energy dissipation

The options we considered for energy dissipation and erosion control for culvert outlets are outlined below. Options were shortlisted from 21 options in the Federal Highways Administration (2006) HEC-14, based on site and hydraulic conditions and application of similar devices on the NGTR. A brief discussion of the merits of each method is provided to highlight which solutions we consider the BPO for the Project.

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.

We assessed all culvert flows and velocities and assigned energy dissipation structures to ensure that downstream erosion potential is minimised.

Energy dissipation structures we identify as the BPO solutions for the Project are described in the sub-sections below the selection flow chart in Figure 13.

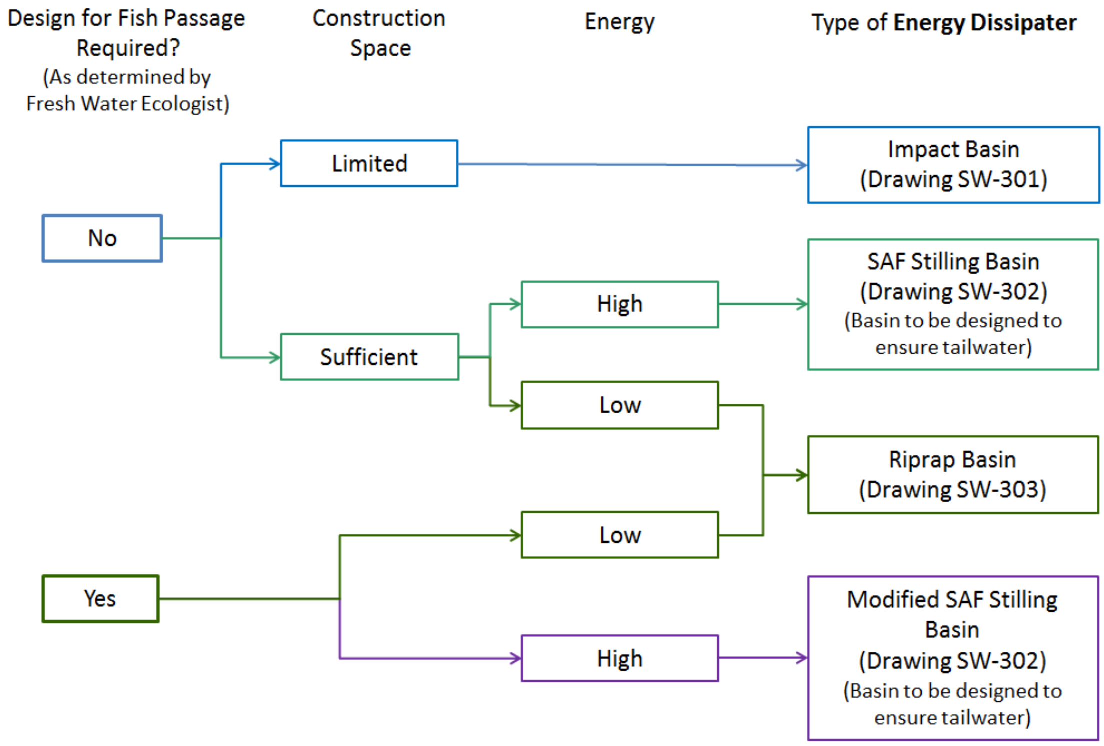

Figure 13: Flow chart for energy dissipation

(a) 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 7 for the Otanerua wetland outfall on 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 extreme difficult to remove any blocked material. Impact basins are not proposed for any culverts but may be used for stormwater outfalls.

Photo 7: Impact basin on NGTR Otanerua Wetland outfall

(b) SAF stilling basin

A Saint Anthony Falls (SAF) stilling basin is a concrete structure that receives discharges from a culvert into a basin via a baffled chute with blocks on the invert. The basin also has baffle blocks and a sill at the downstream end. The sill, in conjunction with a tailwater condition, produces a hydraulic jump. These three elements combine to dissipate energy and minimise erosion downstream. The SAF stilling basin is most appropriate for culvert outfalls with high energy flows.

The SAF stilling basin is not suitable for fish passage and requires a large area. A typical detail for a SAF stilling basin is shown on Drawing SW-302. SAF stilling basins are proposed for many of the culverts where our freshwater Ecologist has determined no need for fish passage (refer Table 3). There is one instance where we propose a modified SAF stilling basin that is engineered for fish passage (Culvert 51000). This modification for fish passage is shown indicatively on the drawing.

(c) 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. Riprap basins are proposed for many of the culvert outlets.

An example of a riprap basin is shown in Photo 8 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.

Table 3 in Section 3.4 identifies the energy dissipation structure we propose for each culvert.

Photo 8: Riprap basin for NGTR Nukumea culverts.

7.8 Debris hazard

7.8.1 Introduction

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. A summary of our risk framework follows.

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.

7.8.2 Risk

The risk associated with debris flow occurrence is a product of the likelihood of debris flows and culvert blockage, and the consequence of this culvert being blocked. This relationship is described in Table 13.

Table 13: Risk matrix for debris flows

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

We categorise the likelihood of debris flow occurrence as follows in Table 14.

Table 14: Likelihood of debris flow occurrence and culvert blockage

Likelihood	Description
Low	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	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	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 in Table 15.

Table 15: Consequence for debris flows

Consequence	Description
Low	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 < 20,000m^3 and less than 3m in depth.
High	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 > 20,000m^3 and more than 3m in water depth.

7.8.3 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. Table 16 lists the mitigation measures we propose for the Project for different degrees of risk of blockage of a culvert by debris flow.

Table 16: Debris blockage mitigation measures

Risk	Mitigation
High	Debris rack upstream of culvert (Drawing SW-305) AND Culvert sized to pass 100 year ARI without heading up
Moderate	Relief inlet (Drawing SW-306)
Low	None

(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 Drawing SW-305.

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 Drawing SW-306. 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.

In addition to the risk framework above, we have oversized culverts longer than a specified length to accommodate access/maintenance requirements. Refer to Section 6.7.2 which summarises the culvert design criteria. This oversizing provides a generous culvert cross-sectional area that results in a generally lower risk of debris blockage for the project.

The debris blockage mitigation measures proposed for the Project are summarised in Table 3.

7.9 Stream diversions

Permanent diversions and flow channels are required to manage surface water for the Project. We have minimised the extent to which stream diversions of main streams are required via the overall route selection process.

Diversions are required:

- Where fill and spoil sites impinge on streams and/or flow channels; or
- Where proposed culverts are built off-line and require a diversion to and from the natural stream to convey the flow.

As part of our BPO process to select a stream diversion type for each specific site, we developed a flow chart that selected the most suitable type of stream diversion based on fish passage criteria. This flow chart is shown in Figure 14.

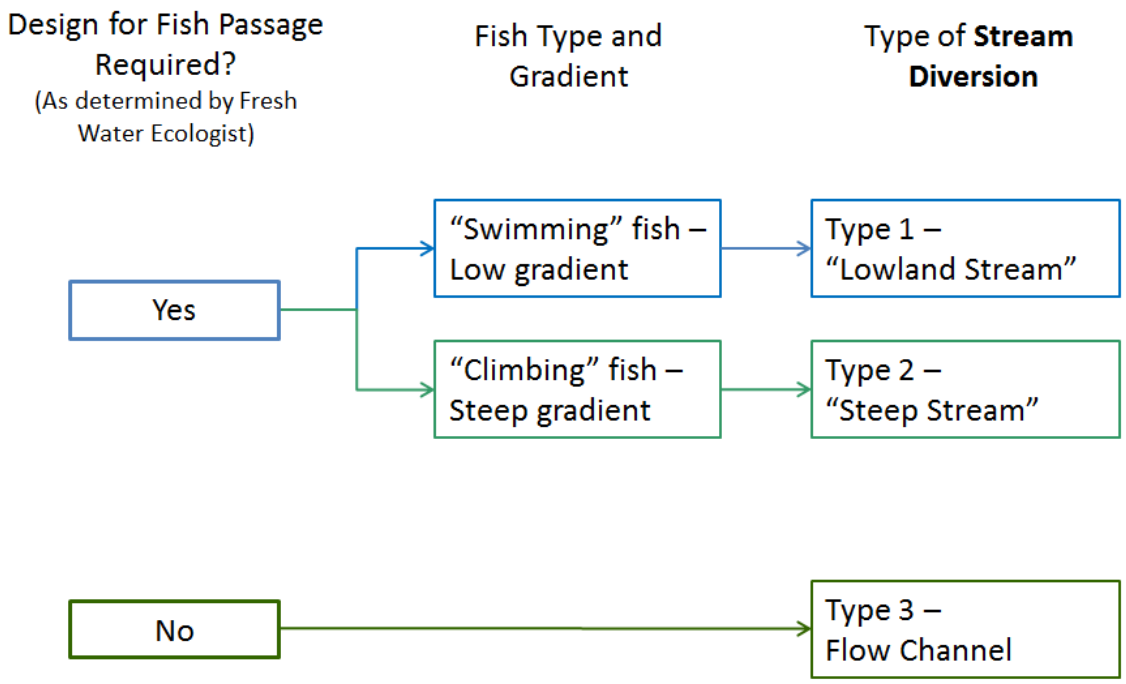

Figure 14: Flow chart for stream diversion type

The Project's freshwater ecologists identified the streams in the Project area requiring fish passage in the Freshwater Ecology Assessment Report. Fish passage is required where there is currently fish habitat in or near the streams being affected, or where there is potential for future fish habitat. We provide fish passage in all these instances for the Project with the exception of two culverts where drop structures are required at the upstream end. These drop structures create a barrier to fish passage. These barriers are a consequence of the elevation of the motorway, the requirement to provide sufficient cover above the culvert, and the extensive streamworks that would be required to maintain a gradient suitable for swimming fish to get from the culvert inlet to the existing stream bed upstream. The ecological effect of these two barriers to fish passage is described in Section 8.5.3.

We developed three stream/channel types based on the flow chart in Figure 14.

Table 17 describes stream diversion requirements we have created for these stream/channel types. We developed these design requirements in collaboration with the Project's freshwater ecologists together with input from Hōkai Nuku.

The starting principle for our design requirements is to minimise adverse environmental effects by recreating habitats for stream diversions that restore streams to a natural state. Figure 15, Figure 16 and Figure 17 provide typical cross sections of the three types of stream diversions we propose.

Table 17: Stream diversion requirements

	STREAM DIVERSION TYPE		
Requirement	**1 Lowland Stream**	**2 Steep Stream**	**3 Flow Channel**
Flow	• Flood conveyance of 100 year ARI rainfall event with stop bank if required; • Low flow channel; • Main channel for the 2 year ARI rainfall event; • Flood berm for larger events; and • Maintain velocity to mitigate ponding and stagnant water.	• Flood conveyance of 100 year ARI rainfall event; • Low flow channel; • Main channel for the 2 year ARI rainfall event; and • Flood berm for larger events.	Flood conveyance of 100 year ARI rainfall event.
Channel Stability	Stable for 2-year ARI floods.	Stable for 2-year ARI floods.	Stable for 100-year ARI floods, lined as appropriate to achieve stability (e.g. grass or rock lined).
In-stream Habitat	• Low continuous gradient; • Meanders; • Complexity (variety of logs and rocks that change flow patterns and provide resting places); and • Continuous low flow channel.	• Steep gradients; • Pools and cascade sequences; • Complexity (variety of logs and rocks that change flow patterns and provide resting places); and • Continuous wetted surface for climbing species.	No requirement for in-stream habitat.

	STREAM DIVERSION TYPE		
Requirement	**1 Lowland Stream**	**2 Steep Stream**	**3 Flow Channel**
Riparian	• Replicate the existing environment as much as possible; • Riparian zone to be 10-20m on either side of the stream edge. Riparian zone to be a heterogeneous planting regime which reflects what is existing. Planting to be species found in the Rodney Ecological District. Planting to replicate lowland and steep streams with riparian planting to include zones for 1 stream, 2 stream edge, 3 littoral and 4 forest in accordance with Drawings SW-401, SW-402 and SW-403; • Recovery of plants and re-planting is encouraged ; • Provide a bat-friendly corridor by inclusion of puriri and taraire trees; and • Establish a closed canopy cover early.		No requirement for riparian planting.

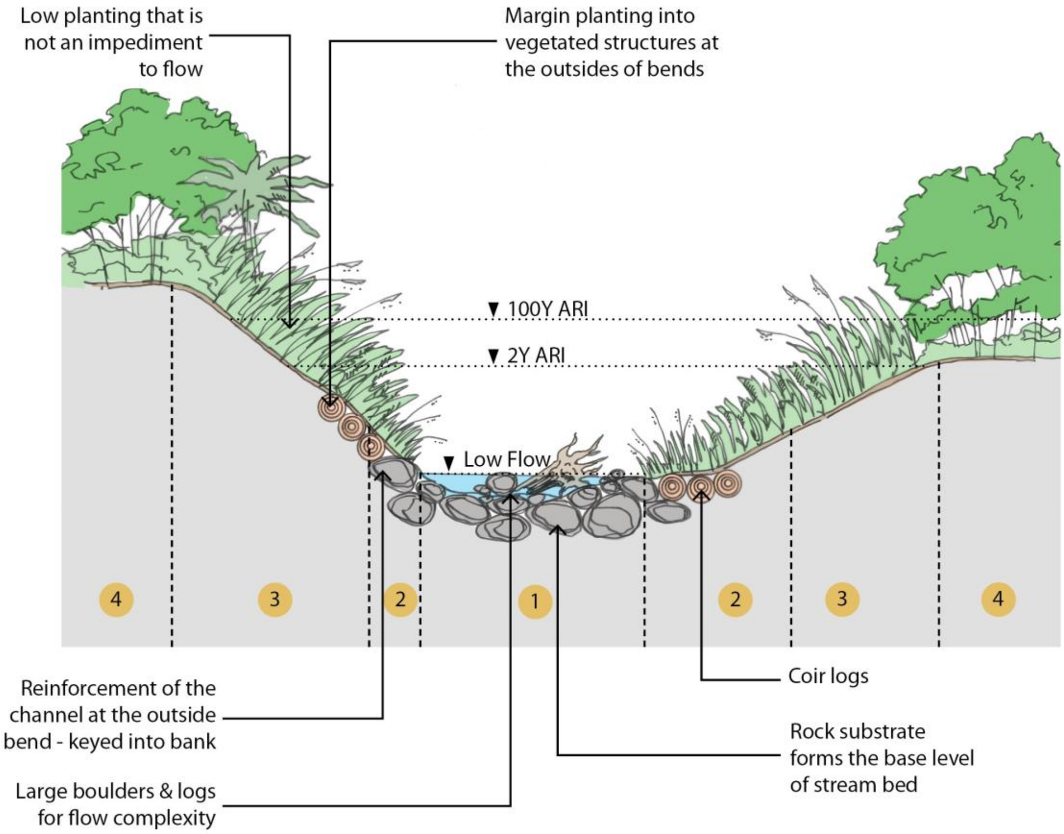

Figure 15: Stream diversion Type 1 – Lowland stream cross section (extract from Drawing SW-401)

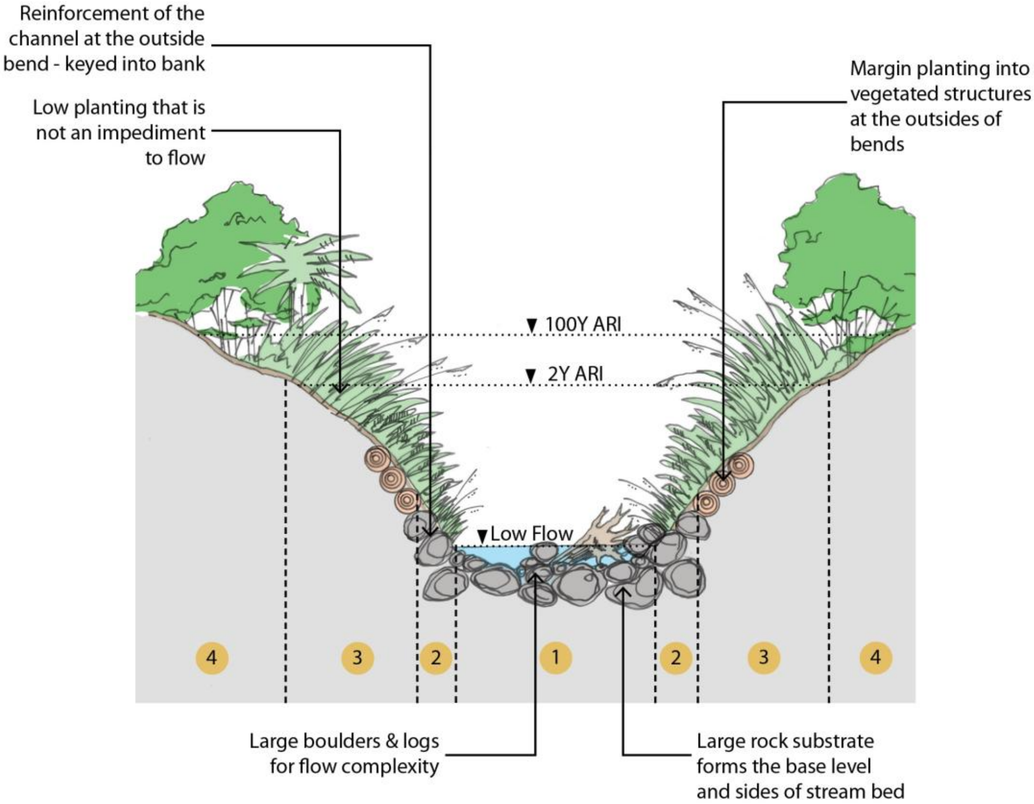

Figure 16: Stream diversion Type 2 – Steep stream cross section (extract from Drawing SW-402)

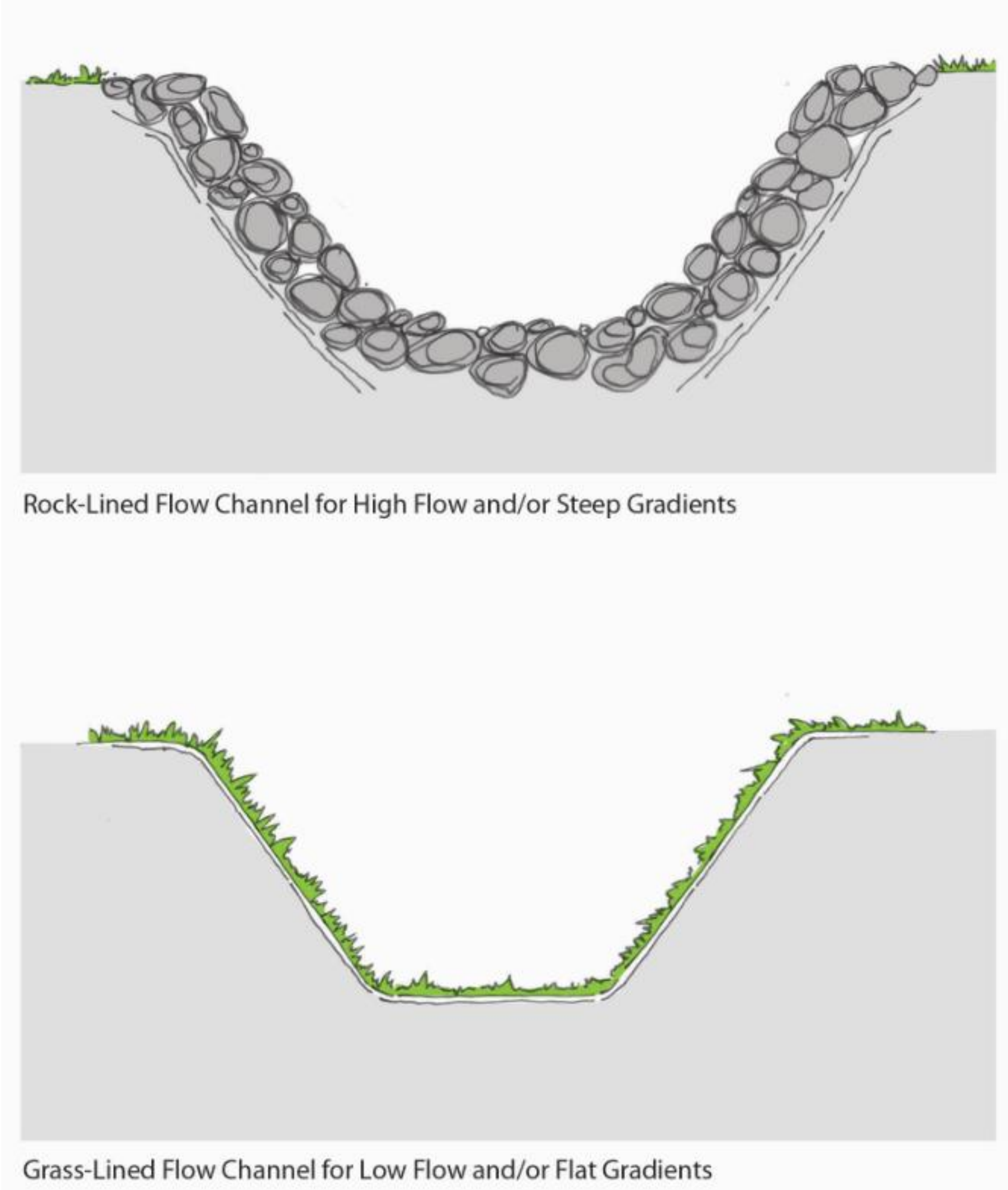

Figure 17: Stream diversion Type 3 – Flow channel cross section (extract from Drawing SW-403)

7.10 Flooding

The Carran Road Sector is a key area for flooding as the motorway crosses the Mahurangi floodplain at Woodcocks Road Bridge, and crosses a major secondary flow path between Woodcocks Road and SH1. Our BPO approach is to minimise the effects of flooding in these areas by changing the alignment of the motorway to avoid the floodplain where possible, and by using bridges to cross the floodplain where necessary to mitigate potential adverse effects where avoidance is not possible.

The Project design team revised the Scheme Assessment Phase alignment in response to new results from the Auckland Council rapid flood hazard modelling. The Scheme Assessment alignment blocked and occupied the secondary flow path. To mitigate effects of this impact on the secondary flow path, we moved the alignment to a position further west to avoid the floodplain. Figure 18 is based on the Auckland Council rapid flood hazard model and shows the Scheme Assessment alignment, the current indicative alignment, and the 100 year ARI floodplain for the Carran Road Sector.

The Carran Road Flood Relief Bridge is provided and sized to pass the 100 year ARI flood where we cross the secondary flow path. We initially sized the Carran Road Flood Relief Bridge with a 28m span and incorporated this into the rapid flood hazard model. The differences between pre and post-development flood flows for the Carran Road Flood Relief Bridge with a 28m span are shown in Figure 19. A 28m span bridge passes the secondary flow but with a reduction in peak flow from $90m^3/s$ to $60m^3/s$. The 28m span bridge also results in an afflux of 250mm upstream of the bridge. These increases in flood levels occur along the Mahurangi River until the Falls Road area. Along the secondary flow path downstream of the Carran Road Flood Relief Bridge the flood levels decrease.

To achieve a higher level of mitigation by a greater reduction of effect, we increased the bridge span at the Carran Road Flood Relief Bridge to 60m, and incorporated this bridge span into the rapid flood hazard model. The differences between pre and post-development flood flows for the Carran Road Flood Relief Bridge with a 60m span are shown in Figure 19. With the 60m span, the Carran Road Flood Relief Bridge can convey the secondary flow with an afflux of less than 100mm.

A 60m span Carran Road Flood Relief Bridge is the BPO that provides an afflux we consider acceptable. The effects of the increase in flood levels associated with the 60m bridge are assessed in Section 8.6.

The hydraulic sizing of both the Carran Road Flood Relief Bridge and the Woodcocks Road Viaduct will be refined during detailed design when further hydraulic modelling will be carried out.

Other options we considered to mitigate the effects of flooding in the Carran Road Sector and decided not to progress were:

- Changes to the Mahurangi River Left Branch to pass more flow;
- Recommending that the NZTA purchase properties affected by flooding; and
- Raising of floor levels affected by flooding.

It could be considered at the detailed design phase to improve the capacity of the secondary flow path at its northern end, which may enable the proposed Carran Road Flood Relief Bridge span to be reduced.

Our assessment of the effects of the Project on flooding is described in Section 8.6.

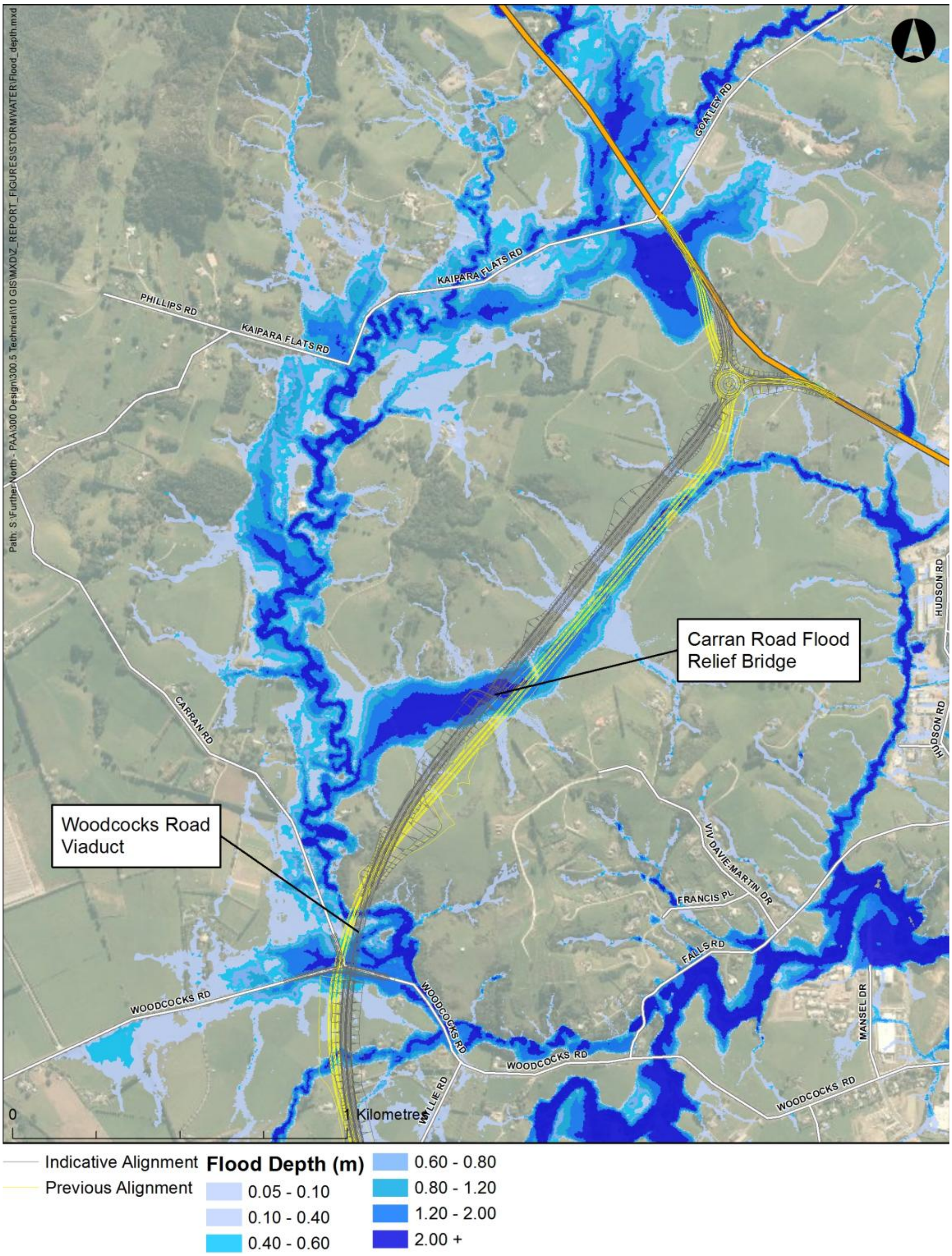

Figure 18: Motorway alignment to avoid floodplain

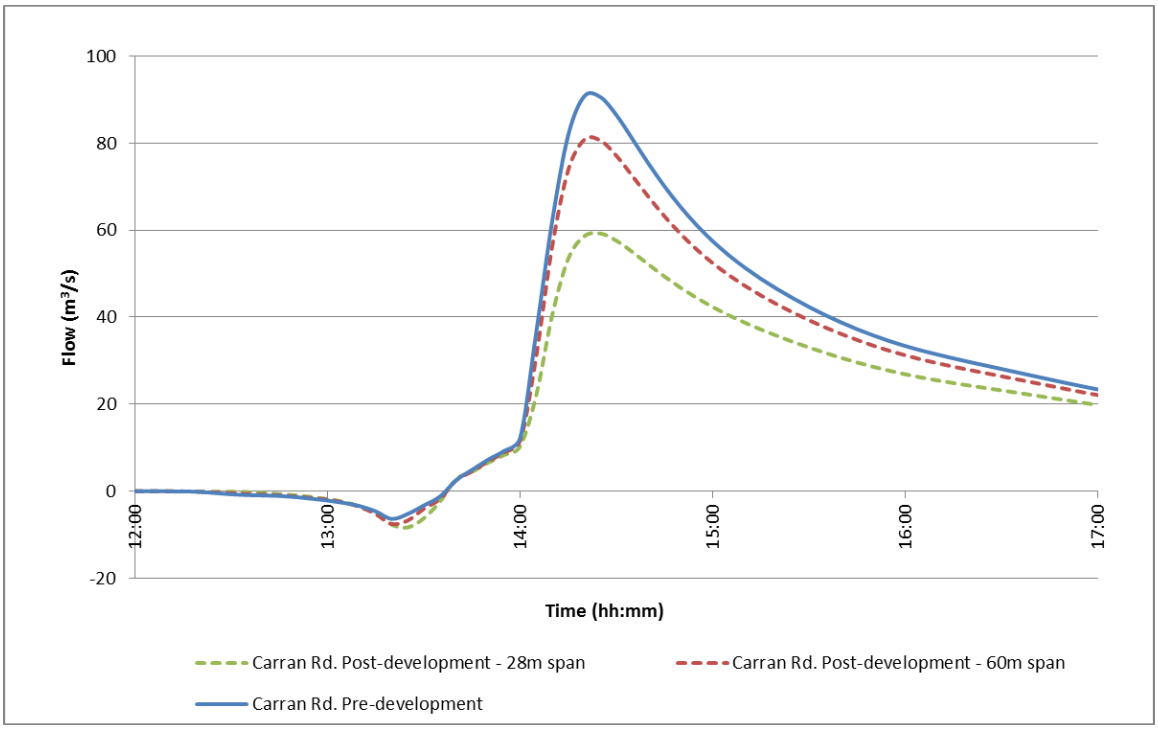

Figure 19 Comparison of 100 year ARI Flow at Carran Road Flood Relief Bridge for a 28m and 60m span

7.11 Spoil disposal

Spoil is material not suitable for placement as engineered fill, or material in excess of the cut/fill balance for that area of the project. A philosophy for the spoil disposal was developed between the key design and environmental personnel in the Project team. The majority of the potential spoil disposal areas identified by the Project team are located close to the alignment and involve extensions to the upstream sides of embankments, using some large gullies above the road. We use some of these spoil disposal areas as platforms for constructed wetlands for stormwater treatment.

All proposed spoil disposal locations within the designation are allowed for in our culvert and stream diversion design. The proposed spoil locations are shown in the drawing set. The headwater extents upstream of culverts are designed to be contained within the footprint of the spoil areas and the proposed designation boundaries where practically possible to do so. There are three locations where predicted headwater extents extend out of the proposed designation boundaries. Our assessment of the effects of these headwater extents is described in Section 8.6.

8. Assessment of effects – operational water management

We have assessed the effects of the Project based on the design that incorporates BPO measures to avoid, remedy and mitigate effects. Overall, we consider the residual effects from the operational water systems we propose to be negligible to minor, with the exception of the flooding predicted where the current design has minor to moderate effects.

The assessment of effects for **stormwater quantity** is summarised as follows:

- Changes in flow, volume and time to peak for the two, 10 and 100 year ARI events at locations downstream of the Project are predicted to be small and have negligible effect on flooding and infrastructure, which confirms that attenuation of flood flows is not required;
- There are changes in flows in tributaries that result from changes to drainage patterns associated with the motorway. Tributaries that receive flow from the motorway have an increased flow with decreases elsewhere. The risk of erosion for tributary streams receiving discharges from the motorway will be mitigated by providing extended detention for all wetlands. Meanwhile, in the main branches of the Mahurangi and Pūhoi rivers the predicted flow changes are within ±5%;
- Energy dissipation structures are proposed for culverts and stormwater outfalls to minimise effects of bed scour and bank erosion in receiving environments;
- The potential effects of the Project on stream bed / channel disturbance are assessed to be moderate due to the loss of stream habitat, but these effects will be effectively mitigated by replacement with natural stream forms and therefore minor overall; and
- The effects of the Project on overland flow are assessed to be minor as these effects will be mitigated by bridges, culverts and stream diversions.

The assessment of effects for **stormwater quality** is summarised as follows:

- Runoff from all new impervious motorway surfaces and rock cuts for the Project will be treated by the wetlands;
- Wetlands are an appropriate BPO method for managing the stormwater run-off from the motorway;
- Wetlands will treat for TSS removal and toxic, persistent and bioaccumulative contaminants;
- Vegetated roadside drains are an appropriate BPO for managing the stormwater run-off from

ancillary roads being constructed or upgraded by the Project;

- Water quality will be maintained with the proposed treatment in place;
- Effects from oil and grease films and gross litter are assessed to be negligible;
- Effects of the wetlands and permanent streamworks on the development of foams and scums in receiving freshwater are assessed to be minor, and there is no change in the risk of scums and foams associated with algal blooms in the harbours;
- Contaminant loads associated with the Project are negligible compared to existing loads;
- Marine sediment quality will have only minor change;
- There may be changes in colour and clarity at discharge locations but these changes will be temporary, and are likely to coincide largely with the natural change in colour and clarity that will occur during storm events;
- There will be no effect on the colour and clarity of water in the lower reaches of the Mahurangi or Pūhoi Rivers, or the Harbours;
- Effects on aesthetics and odour are assessed to be minor; and
- Any physical changes on the surrounding environment from the deposition of sediment are assessed to be minor.

The assessment of effects for **human impacts** is summarised as follows:

- Predicted increases in TSS and contaminants will have minor impact on the suitability of the Mahurangi River water for potable water supply at Warkworth;
- The effects on Warkworth Town potable supply will be minor with the proposed Warkworth bore water supply expected to come on line in 2016 and predicted to provide the main potable water supply by 2021;
- Effects on human health and amenity are assessed to be minor;
- Effects on stock drinking water quality are assessed to be negligible; and
- Effects on water users are assessed to be minor.

The assessment of **ecological effects** is provided in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report. The following information supports those assessments.

- Nine stream/rivers crossings will have bridges and therefore avoid the ecological effects of culverts;

- Fish passage in culverts will be provided for all permanent streams with the exception of only two streams where the effects of not providing fish passage are presented in the Freshwater Ecology Assessment Report;
- Fish passage in culverts will be provided for all instances where there are fish present or potential for fish habitat upstream in intermittent streams;
- The assessment of the effects on stream lengths due to culverts and stream diversions is in the Freshwater Ecology Assessment Report; and
- Stream diversion types 1 and 2 will have a natural form and include riparian planting and provide for fish habitat and passage.

The Project has an impact on **flooding** in the Carran Road Sector due to the minor afflux upstream of the Carran Road Flood Relief Bridge. The flooding effects are partly mitigated by avoidance and mitigation measures incorporated in the Project, but the residual effects remain minor to moderate.

We have assessed the effects of the operational water management aspects of the Project. The following section outlines the assessment criteria (established in section 5.4) and records the outcomes of our assessment. These assessment criteria are organised under the following sections and sub-sections outlined in Table 18.

Table 18: Index to assessment criteria

Section		Sub-section	
8.1	Best Practicable Option	-	-
8.2	Stormwater quantity	8.2.1 8.2.2 8.2.3 8.2.4	Attenuation Bed/channel disturbance Erosion control at stormwater outfalls Overland flow
8.3	Stormwater quality	8.3.1 8.3.2 8.3.3	Water quality treatment Aesthetics and odour Sediment discharge
8.4	Human impacts	8.4.1 8.4.2	Human health Water users
8.5	Ecological effects	8.5.1 8.5.2 8.5.3	Protection of aquatic ecosystems habitat Effects of piping / culverting (habitat loss) Fish passage

Section		Sub-section	
8.6	Flooding	-	-

Section 9 includes recommendations for consent conditions that are focused on performance levels to ensure all assessment criteria will be satisfied and environmental effects avoided, remedied or mitigated.

In addition to the assessment provided in this section, the effects of stormwater and in particular residual contaminants (after treatment) and change in stormwater flows, are assessed in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

8.1 Best practicable option

For our assessment of BPO for operational water systems, our criteria and considerations (as discussed in Section 5.5) are:

i. *Have regard to the applicant's reason for the proposed choice and any possible alternative methods of discharge, including discharge into any other receiving environment (RMA s105);*

ii. *Incorporate low impact design principles;*

iii. *Discharge water within the catchment from which it originates;*

iv. *Consider operation and management programmes; and*

v. *Consider the overall effects of stormwater discharges and diversion at the discharge points.*

(a) Assessment of effects

Criterion (i) is satisfied by considering alternative methods using the BPO approach to determine the most appropriate stormwater treatment devices, based on the options described in Section 7.

Criterion (ii) is satisfied. Although low impact devices are not proposed, the wetlands chosen as the primary treatment device for the Project include some low impact design principles, as they use natural systems for stormwater treatment. Wetlands are the BPO for stormwater treatment, as opposed to low impact devices because they are more effective, durable and safer/easier to maintain for a motorway application.

Criterion (iii) is satisfied because discharge locations are within the same catchment as from which the discharge originates with only two exceptions.

1) At the divide between the Mahurangi and Pūhoi catchments, an area of 3.2 ha changes from the Mahurangi catchment to the Pūhoi catchment as a consequence of the Project. The change in catchment occurs because the location of the high point in the proposed motorway alignment is north of the natural catchment divide. The change to the catchment represents approximately 0.08% and 0.06% of the wider Mahurangi and Pūhoi catchments respectively.

Our assessment is that this change in catchment will have negligible effect on the overall catchment hydrology. Local differences in flow are discussed in Section 8.2.

2) The diversion of stormwater along the motorway alignment from one sub-catchment to an adjacent sub-catchment is required throughout the Project. Wetlands are not located in each sub-catchment as the catchment supporting such wetlands would be too small. We therefore propose diversion of flow to a downstream sub-catchment. Fewer wetlands are desirable from an operation and maintenance perspective. Our assessment is the effects of these localised differences in sub-catchment flow will be minor. The effects are discussed in more detail in Section 8.2.

Criterion (iv) is satisfied as discussed in Section 7.3. We met with Peter Mitchell of the AMA to get operation and maintenance feedback to inform our BPO assessment.

Maintenance of wetlands and sediment traps is required. For wetlands the maintenance frequency will need to be higher in the early years after construction to remove sediment and to support the development of healthy wetland plants. The design and construction team should document maintenance requirements for wetlands.

Criterion (v) is satisfied by a combination of energy dissipation and appropriate stream rehabilitation typologies to mitigate adverse effects on the downstream environment from stormwater outfalls and discharge locations. The effects of stormwater discharges with regard to erosion are discussed in Section 8.2.

We have applied a BPO approach to avoid, remedy and mitigate the Project's potential adverse effects and satisfy the five criteria detailed above. We recommend a consent condition requiring the consent holder to document the operation and maintenance of stormwater treatment devices.

8.2 Stormwater quantity

8.2.1 Attenuation

For our assessment of attenuation, we consider the method of stormwater disposal must minimise changes to the pre-development hydrological regime. In particular, our criteria and considerations (as discussed in Section 5.5) are:

i. The peak flows for the two year and 10 year ARI post–development events shall not be greater than the corresponding peak flows for pre-development events;

ii. The volume of stormwater runoff for post-development events shall be minimised; and

iii. The time of concentration for post-development events shall be maximised so that it is as close as practicable to those for pre-development events.

(a) Assessment of effects

We assessed **criterion (i)** and have determined that no attenuation of runoff for the 2, 10 and 100 year ARI rainfall events for flood mitigation is required.

The impervious area of the Project associated with the motorway surface and rock cuts are relatively small compared to the total area of the Pūhoi and Mahurangi catchments. The Project results in a change to impervious land cover of 0.61% for the Pūhoi catchment, and 0.91% for the Mahurangi, refer to Table 19.

The runoff characteristics of cuts and fills associated with the Project will change due to the earthworks. We have assessed these altered pervious areas with pre-development curve numbers (CN) of 74 for pasture and 70 for forestry/bush. We changed these curve numbers to a CN of 79 for the post-development cuts and fills. These changes affect a relatively small area by a small amount (CN changes of 5 to 9, refer Table 9).

Table 19: Changes in catchment land-use due to the Project

Catchment	Total Catchment Area – Post-development (ha)	New Impervious Area		Altered Pervious Area (increased CN number)	
		Area (ha)	% of Total Catchment	Area (ha)	% of Total Catchment
Pūhoi	5141	34	0.6	58	1.1
Mahurangi	3829	38	0.9	85	2.2

*1 Catchment areas based on the XP-SWMM model extend to the downstream extent of the Project.

These changes in land-use (new impervious area and altered pervious areas) due to the Project will cause an increase in post-development peak flows. However, this increase is partially offset by the longer flow paths for the motorway drainage as it is conveyed along the alignment prior to discharge. Runoff is conveyed along the motorway to wetlands, which discharge to the streams at these locations. The other change is the transfer of 3.2ha from the Mahurangi catchment to the Pūhoi catchment.

With no attenuation provided, there is an overall slight increase in peak flow in the Pūhoi catchment (refer Table 20). In a 100 year ARI rainfall event the modelled peak flow increases by 0.13%. In a 10 year event the modelled peak flow increases 0.44% and in a 2 year event the modelled peak flow increases by 0.67%. The measuring point for this assessment is the Pūhoi Estuary immediately downstream of the Project (tidal changes to flows are not considered). Therefore as these flow changes are small, we consider the overall effects of the Project on the Pūhoi catchment flows to be negligible.

With no attenuation provided, there is an overall slight increase in peak flow in the Mahurangi catchment (refer Table 20). In a 100 year ARI rainfall event the modelled peak flow increases by 0.47%. In a 10 year ARI rainfall event, modelled peak flow increases by 0.88%, and in a 2 year ARI rainfall event the modelled peak flow increases by 2.15%. The measuring point for this assessment is the Mahurangi River immediately downstream of Falls Road. Therefore, as these flow changes are small we consider the overall effects of the Project on Mahurangi catchment flows to be negligible.

In summary, we consider the overall effects of the Project on the receiving catchments to be negligible. We determined from this assessment that **no** attenuation of runoff for the two year, 10 year and 100 year ARI rainfall events for flood mitigation is required.

Table 20: Changes in peak flows due to the Project

Catchment	Percentage increase in Flow (%)		
	100 year ARI rainfall event	10 year ARI rainfall event	2 year ARI rainfall event
Pūhoi	0.16	0.26	1.35
Mahurangi	-0.18	0.12	0.57

We assessed **criterion (ii)** and consider the corresponding stormwater runoff volume changes to be small with minor adverse effects. Refer to Table 21, Table 22 and Table 23 for details.

Table 21: Changes in runoff volume due to the Project for 100 year ARI rainfall event

Catchment	Pre-development volume (m3)	Post-development volume (m3)	Change in volume (%)
Pūhoi	13,373,000	13,518,000	1.08
Mahurangi	11,505,000	11,568,000	0.55

Table 22: Changes in runoff volume due to the Project for 10 year ARI rainfall event

Catchment	Pre-development volume (m3)	Post-development volume (m3)	Change in volume (%)
Pūhoi	7,718,000	7,864,000	1.90
Mahurangi	6,678,000	6,743,000	0.98

Table 23: Changes in runoff volume due to the Project for 2 year ARI rainfall event

Catchment	Pre-development runoff volume (m3)	Post-development runoff volume (m3)	Change in volume (%)
Pūhoi	3,542,000	3,700,000	4.46
Mahurangi	3,235,000	3,304,000	2.12

Criterion (iii) is satisfied as the time of concentration between pre and post-development is matched as close as practically possible. This matching of time of concentration is demonstrated by hydrographs in Figure 24 to Figure 38 based on locations indicated in Figure 20 to Figure 23. The hydrographs show negligible change in the timing of peak flows in the affected catchments. Stream diversions are established as close to their original locations as practicable. The natural stream types will have similar velocities to the existing streams thereby matching times of concentration as close as possible to the pre-development level.

Overall, we consider the effects of changes in stormwater quantity from the motorway on the existing environment to be minor and that flood attenuation is not required. We recommend a consent condition requiring extended detention for stormwater treatment devices that discharge to stream environments. Monitoring over a limited post-construction period is also recommended as a condition of consent for those streams where there is an increase in flow predicted.

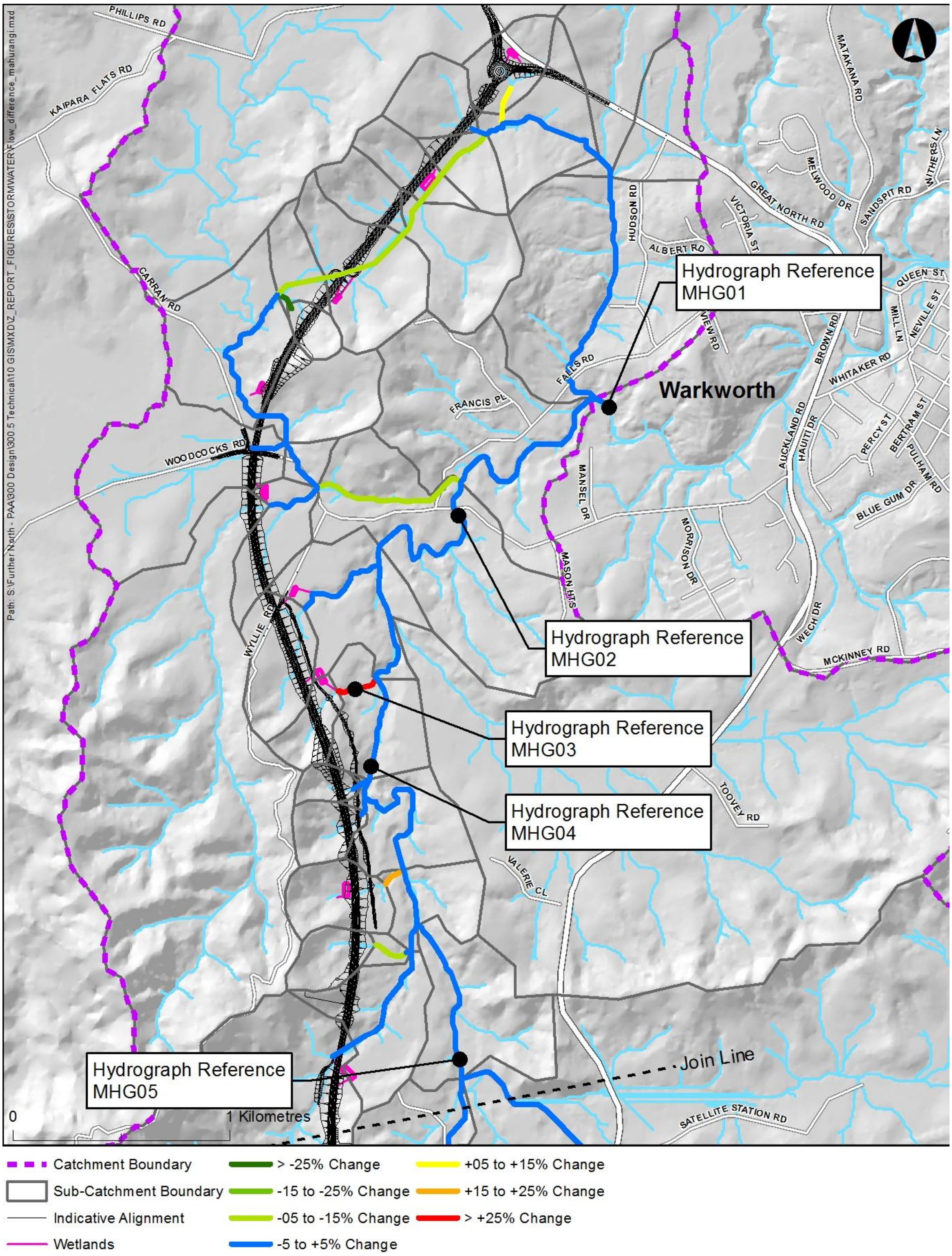

Figure 20: Changes in flow in streams due to motorway for 100 year ARI rainfall event – Mahurangi Catchment (1 of 2)

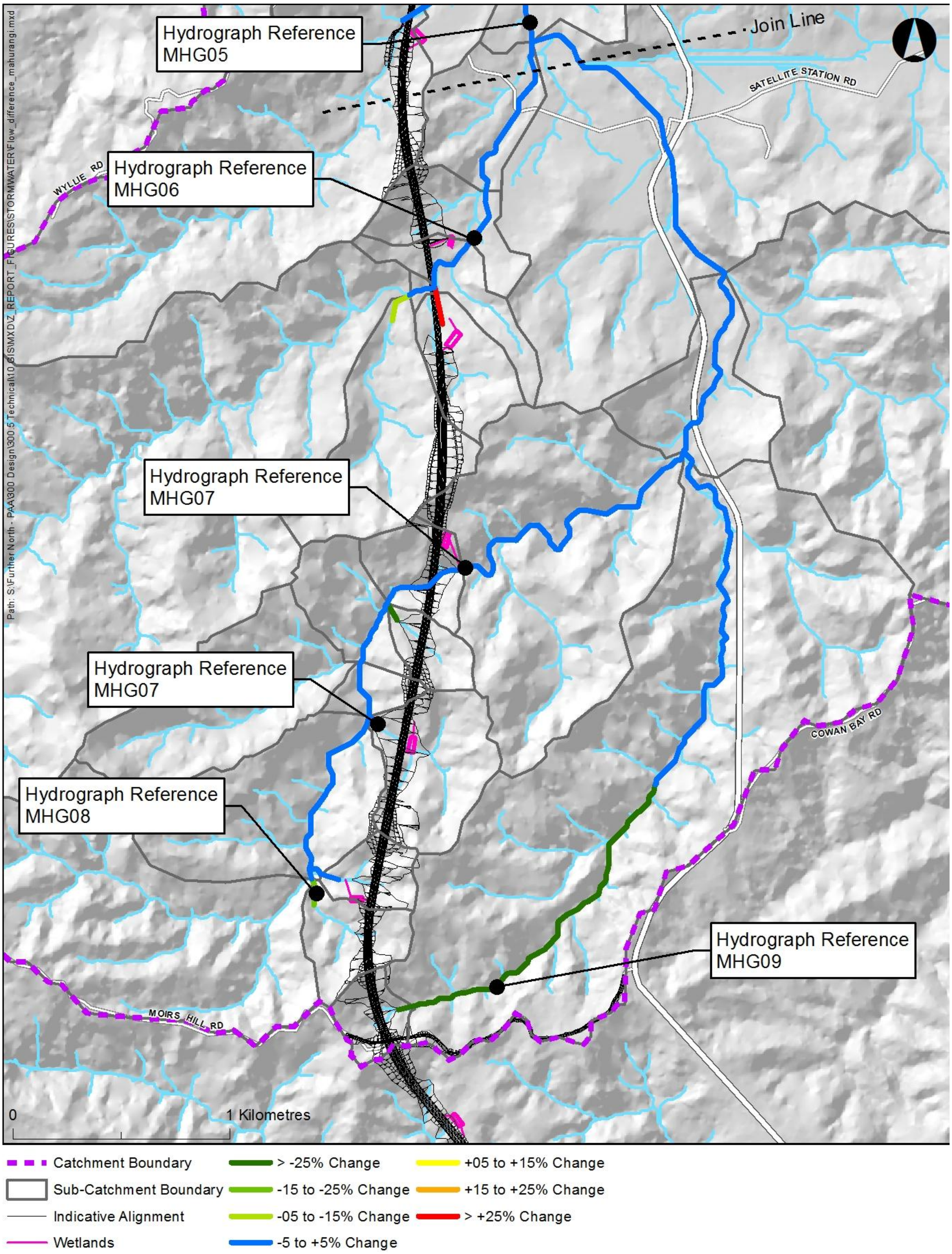

Figure 21: Changes in flow in streams due to motorway for 100 year ARI rainfall event – Mahurangi Catchment (2 of 2)

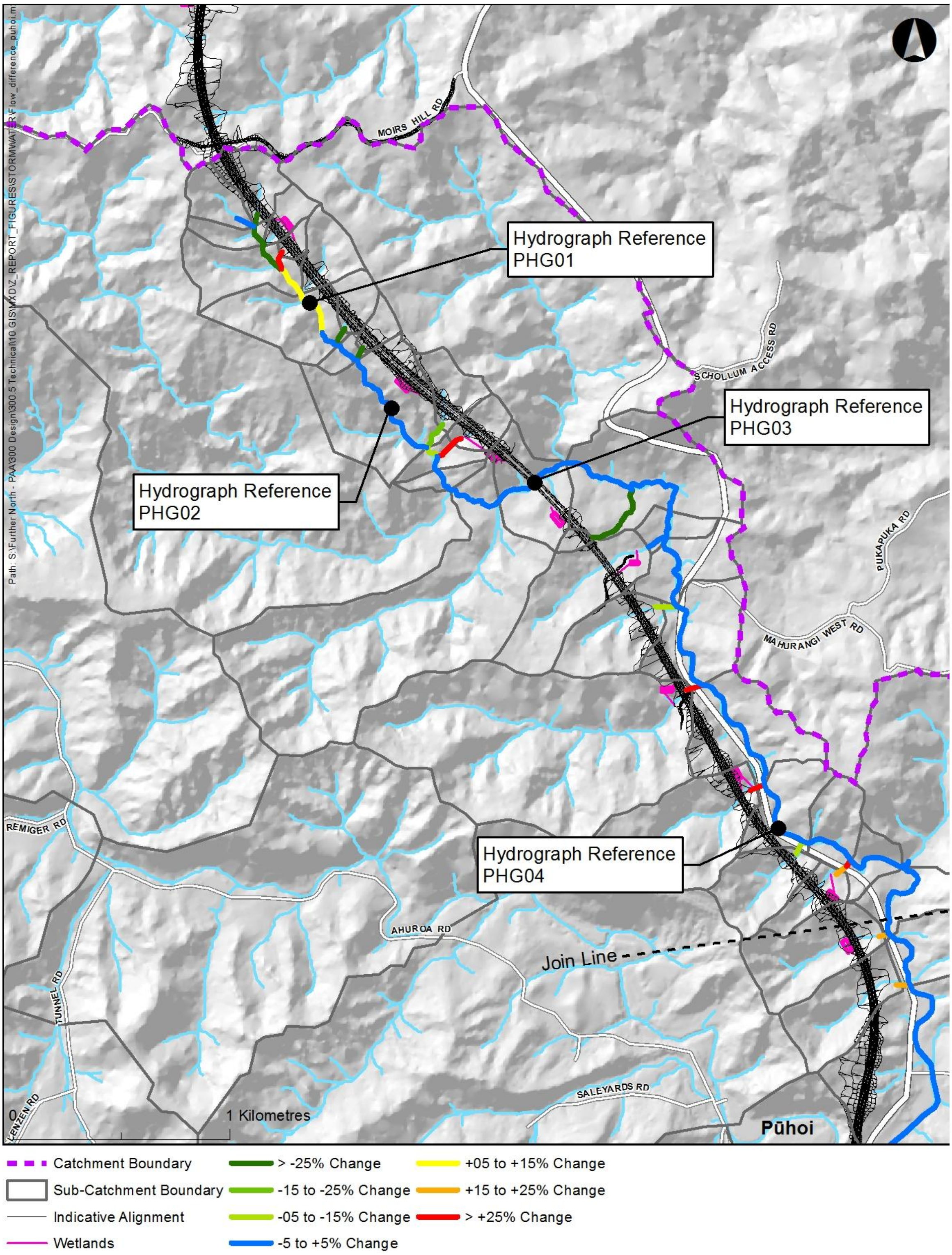

Figure 22: Changes in flow in streams due to motorway for 100 year ARI rainfall event – Pūhoi Catchment (1 of 2)

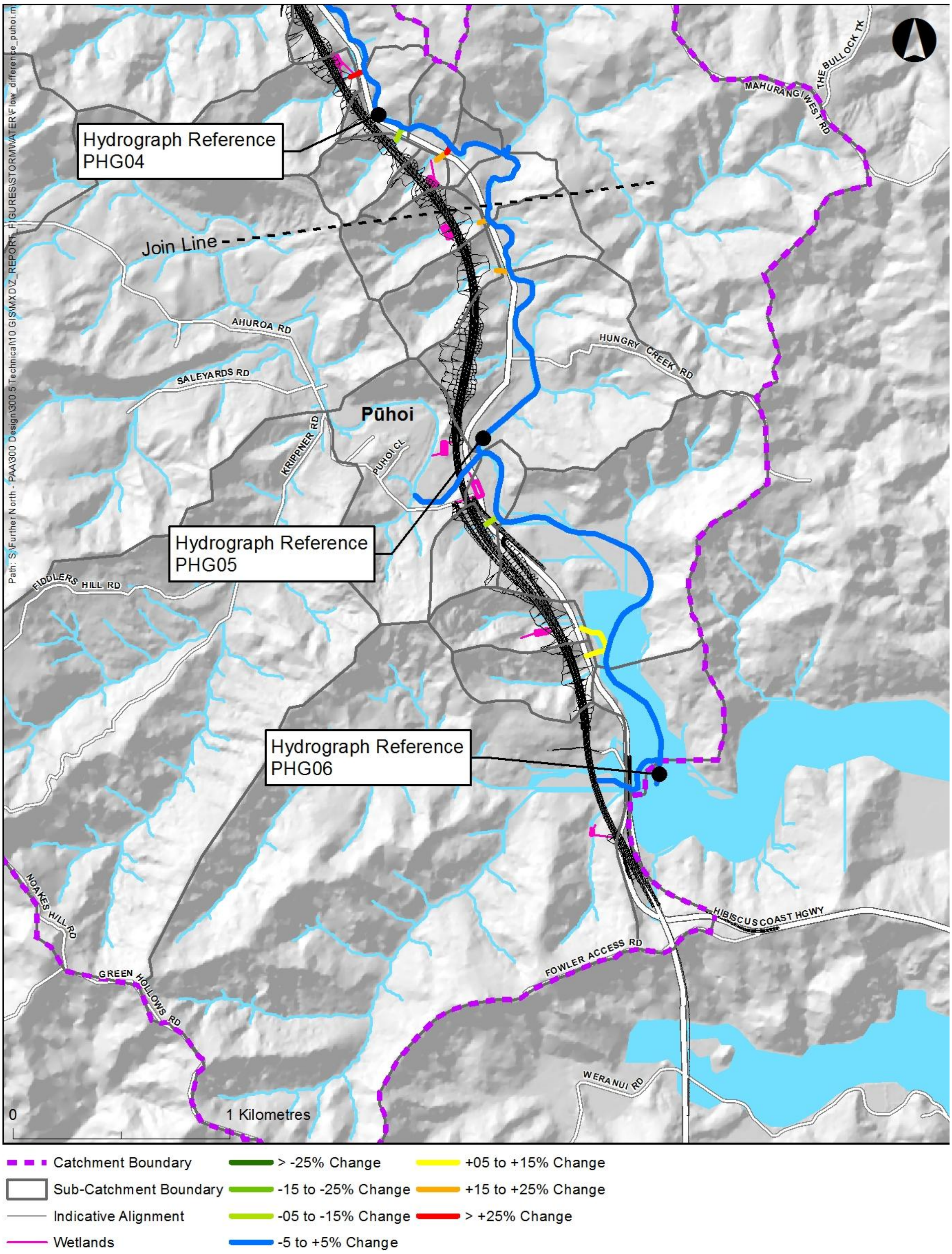

Figure 23: Changes in flow in streams due to motorway for 100 year ARI rainfall event – Pūhoi Catchment (2 of 2)

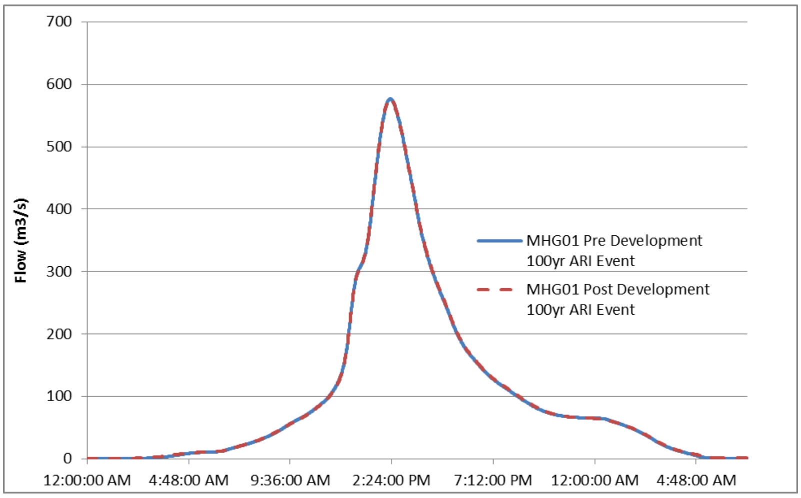

Figure 24: Mahurangi Hydrograph 01 – Flow change due to the Project

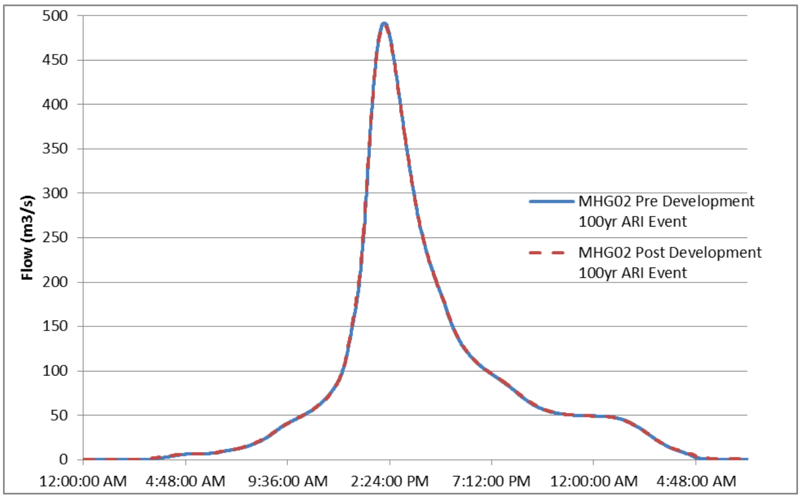

Figure 25: Mahurangi Hydrograph 02 – Flow change due to the Project

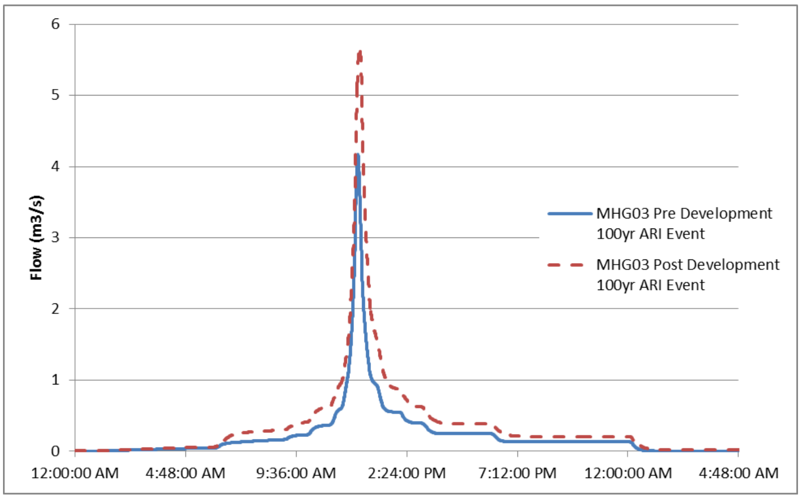

Figure 26: Mahurangi Hydrograph 03 – Flow change due to the Project

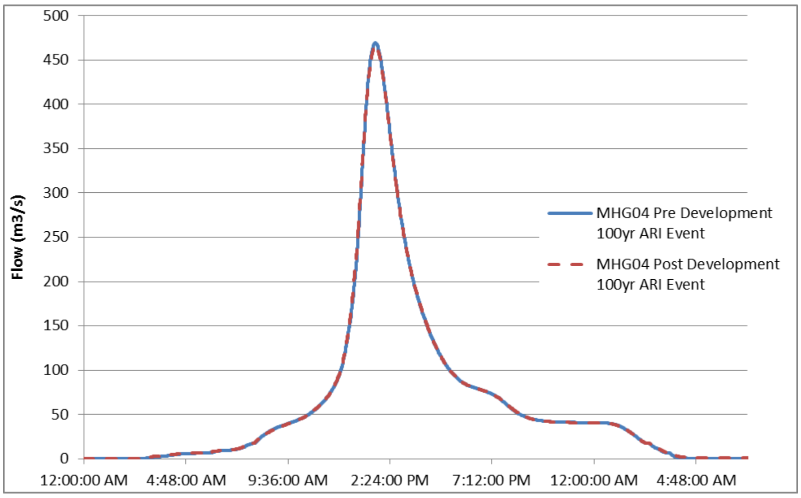

Figure 27: Mahurangi Hydrograph 04 – Flow change due to the Project

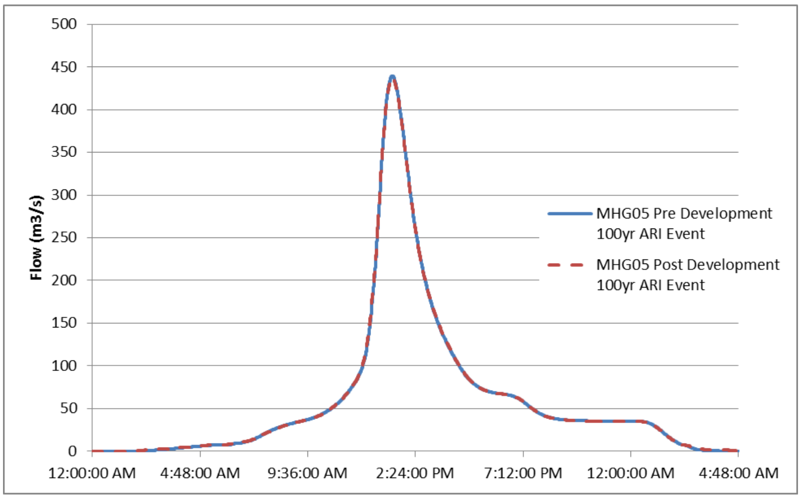

Figure 28: Mahurangi Hydrograph 05 – Flow change due to the Project

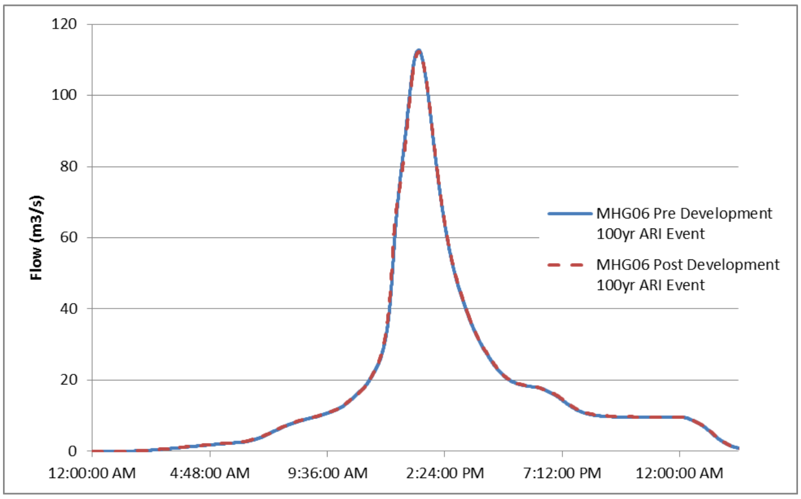

Figure 29: Mahurangi Hydrograph 06 – Flow change due to the Project

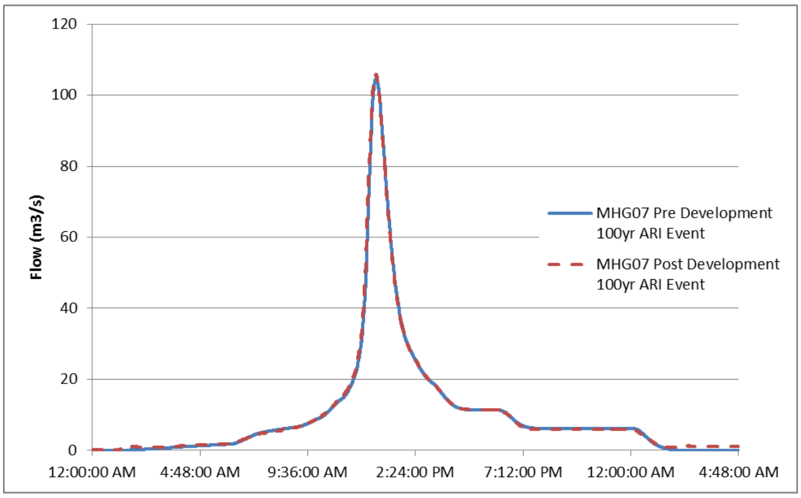

Figure 30: Mahurangi Hydrograph 07 – Flow Change due to the Project

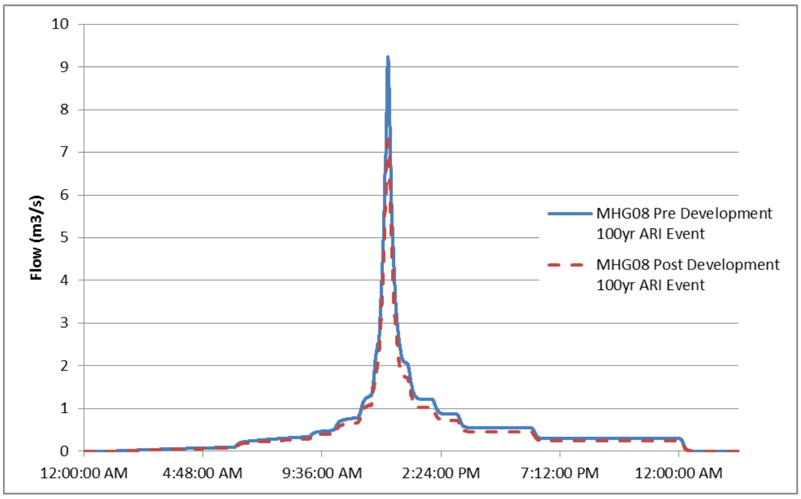

Figure 31: Mahurangi Hydrograph 08 – Flow change due to the Project

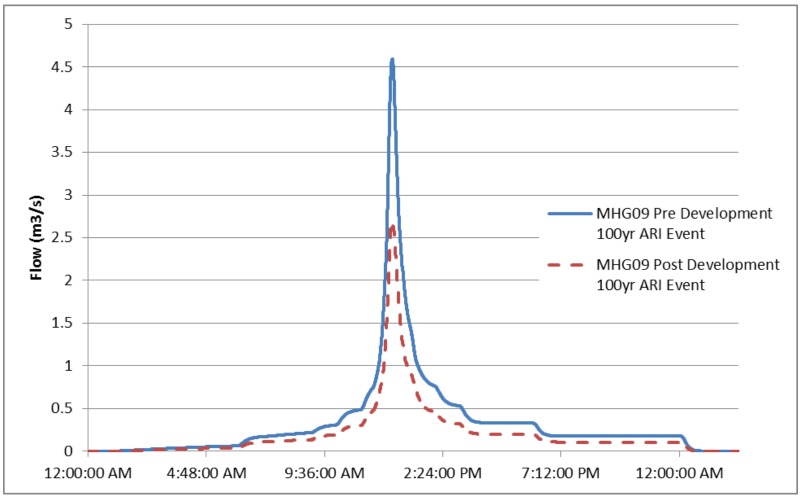

Figure 32: Mahurangi Hydrograph 09 – Flow change due to the Project

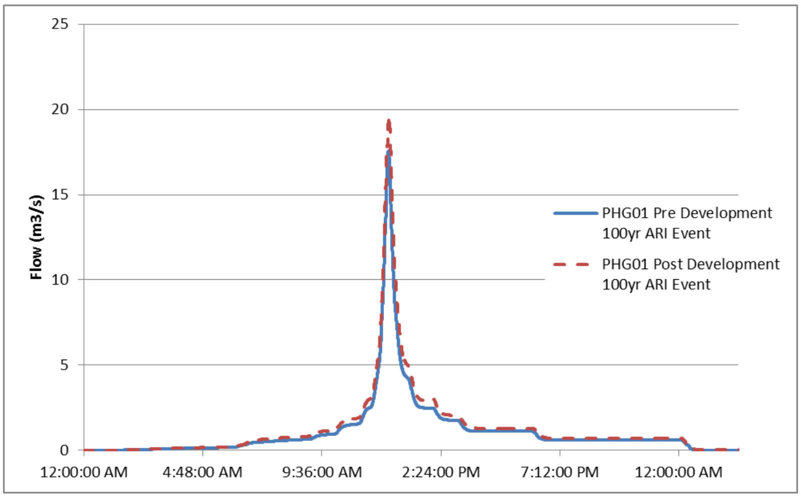

Figure 33: Pūhoi Hydrograph 01 – Flow change due to the Project

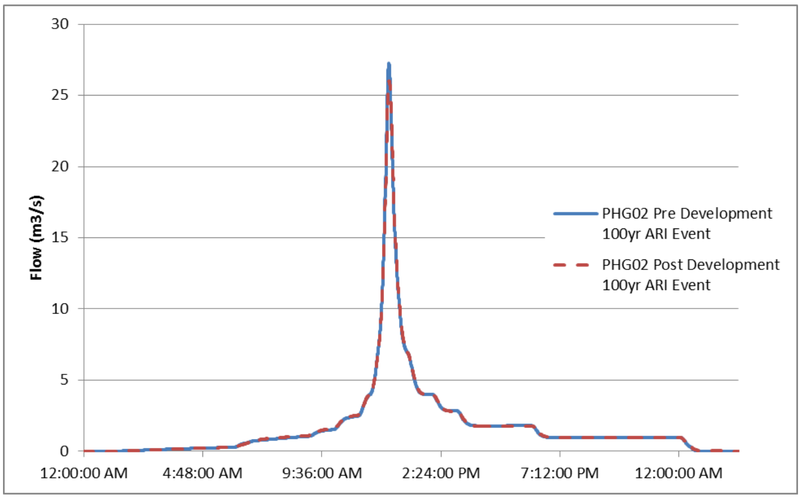

Figure 34: Pūhoi Hydrograph 02 – Flow change due to the Project

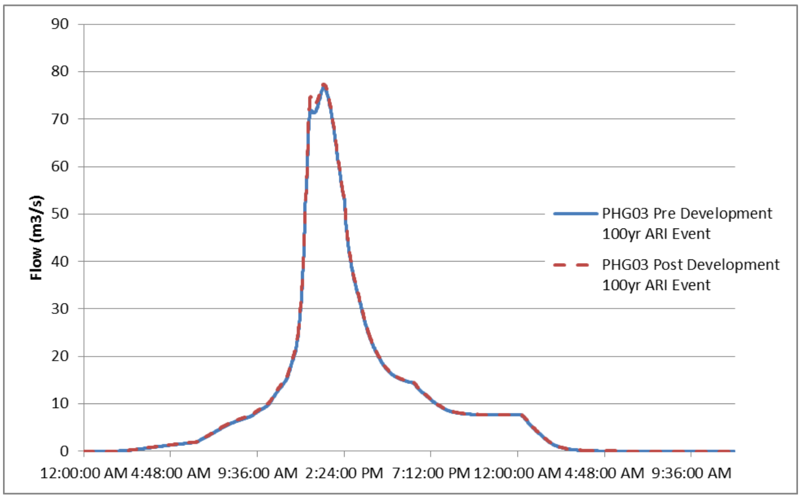

Figure 35: Pūhoi Hydrograph 03 – Flow change due to the Project

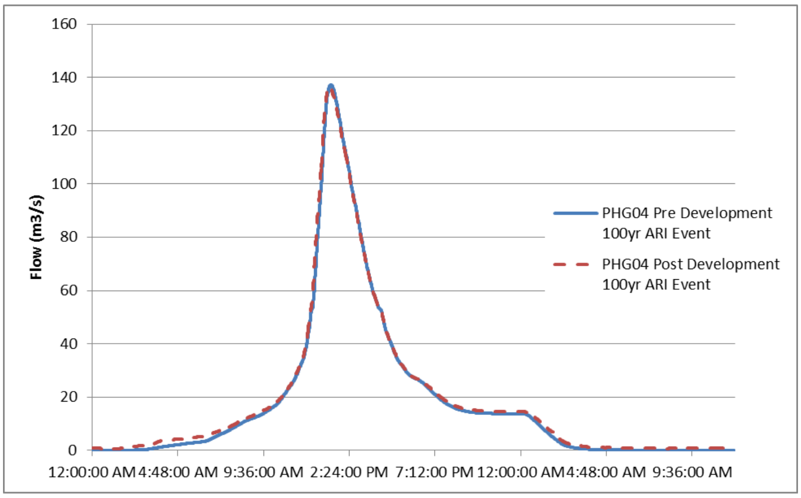

Figure 36: Pūhoi Hydrograph 04 – Flow change due to the Project

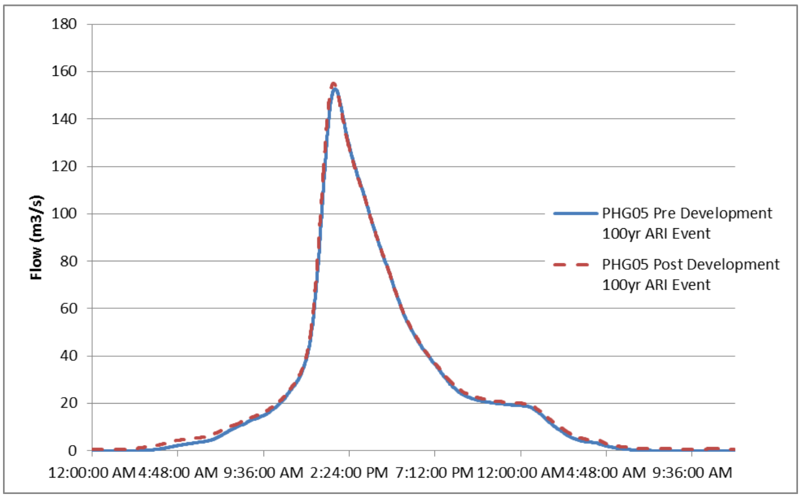

Figure 37: Pūhoi Hydrograph 05 – Flow change due to the Project

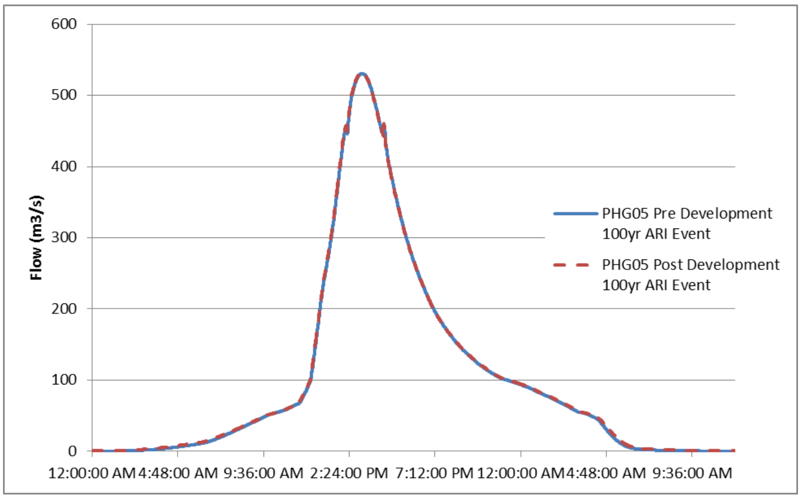

Figure 38: Pūhoi Hydrograph 06 – Flow change due to the Project

8.2.2 Bed / channel disturbance

For our assessment of bed / channel disturbance, our criteria and considerations (discussed in Section 5.5) are:

i. Stormwater disposal shall not cause downstream channel erosion; and

ii. Avoid, remedy or mitigate significant adverse changes to a river / stream bed morphology and flow hydraulics.

(a) Assessment of effects

Criterion (i) is satisfied and has been assessed with the hydrological model and energy dissipation structures at outfalls described below.

The change in drainage patterns associated with the Project causes changes in the spatial distribution of stream flows as shown in Figure 20 to Figure 23. These figures are for the extreme 100 year ARI rainfall event and are indicative of the changes we would expect for lesser events. These changes in spatial distribution result in an increase in flows in the tributary streams where the motorway discharges and there are flow decreases elsewhere. Examples of the tributary streams with larger flow increases are at MHG07 (Figure 30) and MHG08 (Figure 31), whereas MHG09 (Figure 32) shows a large flow increase.

The flow changes are within ±5% in the main streams of the Mahurangi and Pūhoi Rivers.

Our assessment of the effects of the Project on bed / channel disturbance has been supported by site visits to key locations. An example where our assessment is supported by knowledge gained on site is in the vicinity of the proposed Perry Road Viaduct, south abutment. The streams in this area are steep banked channels with rock apparent in some locations. The Project causes flow changes within ±5% in the main streams, which will not cause any significant adverse effect to the river / stream bed morphology.

Photo 9: Example of stream bank in Perry Road Viaduct locale.

Tributary streams where there is an increase in flow by more than 5% may have an increased risk of erosion. We mitigate this risk by providing extended detention for all wetlands that discharge to stream environments. The extended detention approach is the BPO in TP10 for managing the potential for stream erosion. Through this mitigation we consider that Criterion (i) is satisfied.

Criterion (ii) for bed /channel disturbance is satisfied by the indicative alignment avoiding main stems of the streams where possible and through the use of bridges and/or viaducts. However, it has not been possible to avoid the tributary streams as the alignment crosses many sub-catchments. Mitigation for the effects of the Project on these tributary streams is required.

The mitigation to satisfy Criterion (ii) has been by inclusion of stream diversions that replicate the stream bed morphology and flow hydraulics of the natural stream being diverted. Typical cross sections for each type are shown in Figure 15, Figure 16 and Figure 17 in Section 7.9.

We determined the appropriate stream diversion type for each specific site by the BPO assessment described in Section 7.9. Types 1 and 2 are natural stream forms that replicate the stream bed morphology and the flow hydraulics of the natural stream being diverted, whereas Type 3 only provides for flow requirements. The length of each type applied to each stream diversion is shown in Table 3 in Section 3.4. We developed the design requirements for stream diversions in collaboration with the Project's engineers and ecologists, with input also provided from Hōkai Nuku.

Table 24 and Table 25 show the length of streams disturbed in the Pūhoi and Mahurangi catchments respectively.

Table 24: Streams disturbed in the Pūhoi Catchment

Stream	Stream Loss (m) (Lost Habitat)	Stream Diversion Proposed (m) (New Habitat)	Net Change in Habitat (m)
Permanent Stream	1013	108	-905
Intermittent Stream	3388	0	-3388

Table 25: Streams disturbed in the Mahurangi Catchment

Stream	Stream Loss (m) (Lost Habitat)	Stream Diversion Proposed (m) (New Habitat)	Net Change in Habitat (m)
Permanent Stream	3469	2586	-883
Intermittent Stream	4144	381	-3763

The proposed culverts for the Project and any stream diversions will be positioned so that the gradient and alignment are as close to the existing stream as possible. This approach should minimise any potential change in velocity of flow and minimise the potential for erosion or deposition. Therefore Criterion (ii) is satisfied and also Section 8.3.3 for sediment discharges.

Overall, we consider the physical effects of the Project on stream bed / channel disturbance to be minor after mitigation. The ecological effects of the stream diversions are assessed in the Freshwater Ecology Assessment Report. We recommend consent conditions requiring:

- Extended detention for wetland discharges to streams;
- Stream diversions with natural stream forms where the diverted streams are permanent and support fish habitats; and
- Stream diversion requirements that include channel stability criteria.

8.2.3 Erosion control at stormwater outfalls

For our assessment of erosion control at stormwater outfalls, our criterion and consideration (Section 5.5) is:

- All stormwater outfalls shall incorporate energy dissipation and/or erosion protection measures as required, minimising bed scour and bank erosion. The design of stormwater outfalls shall assess various rainfall events and tailwater levels (stream and sea levels) to ensure the critical storm event is considered in the design.

(a) Assessment of effects

The criterion is addressed by providing energy dissipation and/or erosion protection measures at all culvert and pipe outfalls, including culverts proposed for the ancillary roads.

The energy dissipation measures proposed for culvert outfalls are summarised in Table 26. The concept design of the energy dissipation structures was based on the 10 year ARI rainfall event. The design will need to be further developed at the Project's detailed design stage to meet the criteria for various flow/flood events and for the corresponding tailwater conditions.

We assessed the change in flow velocity at proposed culvert outfalls based on the 2 year ARI flow, as these storm events are significant with regard to potential erosion of a streambed. We compared peak flow velocities for a two year ARI rainfall event for culvert outlets with energy dissipation, to pre-development conditions. This comparison forms the basis for our assessment of the effects of each outfall on its respective receiving environment. The energy dissipation structures generally reduce the discharge velocities to similar or less than the pre-development (existing stream) level. Where there is a decrease in velocity post-development, we can be confident that there will be no erosion of the stream as velocity will quickly return to the natural pre-development stream velocity as flow continues downstream.

Our assessment of the effects of the Project on erosion has been supported by site visits to key culvert locations. An example where our assessment is supported by knowledge gained on site is at the location of proposed concrete arch culvert 54700. Bedrock was sighted in the existing stream bed at the approximate location of the culvert outlet (refer to Photo 10). Bedrock is resistant to erosion and if it exists in the bottom or sides of the stream channel, this provides protection against degradation. We can be confident that there is low risk of erosion of the stream bed and banks at the outlet of culvert 54700.

Photo 10: Bedrock sighted at outlet of culvert 54700.

A number of ancillary roads will be constructed or upgraded as part of the Project. These include the proposed access road off Wyllie Road, upgrades to the Perry Road Viaduct access road and to Moirs Hill Road. Upgrades to three existing SH1 culverts will also be needed (refer Section 3.2).

Where there are existing culverts at the ancillary roads being upgraded, these will be considered during the detailed design phase with energy dissipation structures incorporated as required. Where new culverts are required, the gradient and alignment of these culverts will be considered to minimise adverse effects on an existing river / stream.

We also propose that outfalls from the wetlands should incorporate erosion protection measures similar to those proposed for culverts to minimise bed scour and bank erosion in the receiving waterway. Typically this protection will be an energy dissipation device and/or rock apron for erosion protection. We have not designed these erosion protection measures as part of our assessment as the detail for the discharge pipelines from the wetlands is dependent on the flow, slopes and space available at the outlet. Flow, slopes and space constraints are all matters that will be addressed in the detail design phase. These outfalls were constructed at a number of locations on the NGTR; refer to Otanerua Wetland outfall in Photo 7.

The energy dissipation structures we propose for the Project's culverts and stormwater outfalls will minimise bed scour and bank erosion in receiving environments. Overall, we consider the effects of the Project on erosion at stormwater outfalls to be minor. We recommend a consent condition requiring:

- Erosion control for culverts and stormwater outfalls to minimise bed scour and bank erosion in receiving environments; and
- Design of stormwater outfalls to assess various rainfall and tailwater levels to ensure the critical storm is considered.

Table 26: Energy dissipation structures to reduce velocity of stormwater discharge for 2 year ARI rainfall event

Culvert ID	Stream	Culvert diameter (mm)	Energy dissipation structure	2 Year ARI existing stream velocity pre–development*1 (m/s)	2 Year ARI flow velocity pre-energy dissipation (m/s)	2 Year ARI flow velocity post–energy dissipation (m/s)	% Velocity increase (+) / decrease (-) due to Project
ON PROPOSED MOTORWAY ALIGNMENT							
Culvert 63800	P2	1600	SAF Stilling Basin	1.29	4.84	1.29	0
Culvert 63500	P3	1800	SAF Stilling Basin	1.67	6.16	1.67	0
Culvert 63000	P3a	1350	SAF Stilling Basin	1.41	5.49	1.41	0
Culvert 61900	P5	1600	Riprap Basin	0.72	2.68	0.47	-35
Culvert 61600	P6	1800	SAF Stilling Basin	1.45	4.97	1.45	0
Culvert 61300	P6a	1200	SAF Stilling Basin	1.11	5.50	1.11	0
Culvert 61100	P7	1350	SAF Stilling Basin	1.87	7.41	1.87	0
Culvert 60800	P8	2550	SAF Stilling Basin	1.82	6.29	1.82	0
Culvert 60200 ARCH	P9	Arch (7315 Span, 3658 Height)	Riprap Basin	2.28	2.74	0.40	-82
Culvert 59900	P9b	1200	SAF Stilling Basin	0.72	2.65	0.72	0
Culvert 59800	P9a	1600	SAF Stilling Basin	1.49	5.58	1.49	0
Culvert 59400	P10a	1200	SAF Stilling Basin	0.60	2.18	0.60	0
Culvert 58700	P11a	1600	SAF Stilling Basin	1.53	5.27	1.53	0
Culvert 58400	P11b/c	1600	SAF Stilling Basin	1.99	6.88	1.99	0

Culvert ID	Stream	Culvert diameter (mm)	Energy dissipation structure	2 Year ARI existing stream velocity pre–development*1 (m/s)	2 Year ARI flow velocity pre-energy dissipation (m/s)	2 Year ARI flow velocity post–energy dissipation (m/s)	% Velocity increase (+) / decrease (-) due to Project
Culvert 57600	P11f	1600	SAF Stilling Basin	2.04	8.24	2.04	0
Culvert 57400	P11g	1350	SAF Stilling Basin	2.74	10.94	2.74	0
Culvert 57200	P12	1600	SAF Stilling Basin	1.17	3.95	1.17	0
Culvert 56700	M13	1600	SAF Stilling Basin	1.64	6.09	1.64	0
Culvert 56400	M13a	1200	SAF Stilling Basin	1.40	5.89	1.40	0
Culvert 56100	M13b	1200	SAF Stilling Basin	1.12	4.31	1.12	0
Culvert 55300	M13d	2550	Modified SAF Stilling Basin	1.40	8.06	1.40	0
Culvert 54700 ARCH	M15	Arch (8534 Span, 4267 Height)	Riprap Basin	1.92	1.33	0.30	-84
Culvert 53800	M15a	1600	Riprap Basin	0.85	3.16	0.55	-35
Culvert 53000	M16a	1600	SAF Stilling Basin	1.41	5.17	1.41	0
Culvert 51900	M19a	1200	SAF Stilling Basin	0.87	3.26	0.87	0
Culvert 51600	M19b	1200	SAF Stilling Basin	1.36	5.35	1.36	0
Culvert 51300	M19c	1800	SAF Stilling Basin	1.73	6.38	1.73	0
Culvert 51000	M21a	1600	Modified SAF Stilling Basin	1.32	4.86	1.32	0
Culvert 50800	M21b	1200	SAF Stilling Basin	1.12	4.80	1.12	0

Culvert ID	Stream	Culvert diameter (mm)	Energy dissipation structure	2 Year ARI existing stream velocity pre–development[*1] (m/s)	2 Year ARI flow velocity pre-energy dissipation (m/s)	2 Year ARI flow velocity post–energy dissipation (m/s)	% Velocity increase (+) / decrease (-) due to Project
Culvert 50500	M21c	1200	Modified SAF Stilling Basin	1.07	4.26	1.07	0
Culvert 50200	M21d	1600	Riprap Basin	1.13	4.25	0.68	-40
Culvert 49500 ARCH	M22	Arch (7315 Span, 3658 Height)	Riprap Basin	1.84	1.11	0.26	-86
Culvert 48000	M23a	1350	Riprap Basin	0.89	3.38	0.64	-28
Culvert 47700	M23b	1350	Riprap Basin	0.59	2.25	0.43	-27
Culvert 47400	M23c	1600	Riprap Basin	1.57	5.56	0.93	-41
Culvert 47200	M23d	1200	Modified SAF Stilling Basin	1.03	4.39	1.03	0
ON PROPOSED EASTERN LINK TO WARKWORTH							
Culvert 700SH1S	SH1-700	1600	SAF Stilling Basin	1.80	6.91	1.80	0
ON PROPERTY ACCESS ROAD (Off Wyllie Road)							
Culvert 100A	PA100A	1050	Riprap Basin	1.43	3.49	1.20	-16
Culvert 200A	PA200A	900	Riprap Basin	1.22	3.15	1.19	-3
Culvert 500A	PA500A	900	Riprap Basin	1.30	4.89	1.21	-7

Culvert ID	Stream	Culvert diameter (mm)	Energy dissipation structure	2 Year ARI existing stream velocity pre–development*1 (m/s)	2 Year ARI flow velocity pre-energy dissipation (m/s)	2 Year ARI flow velocity post–energy dissipation (m/s)	% Velocity increase (+) / decrease (-) due to Project
ON EXISTING STATE HIGHWAY 1							
SH1-P6	P6	1200	To be detailed in design phase	-	-	-	-
SH1-P8	P8	825	To be detailed in design phase	-	-	-	-
SH1-P9	P9	1600	To be detailed in design phase	-	-	-	-

*1 Pre-development existing stream velocities based on assumed trapezoidal channel cross-section of 3m bottom width and 3:1 (H:V) side slopes.

8.2.4 Overland flow

For our assessment of overland flow, our criterion / consideration (Section 5.5) is:

- *For major overland flow paths in excess of the capacity of the primary systems, secondary flow paths are provided and maintained to allow flow from critical storms, up to the 100-year ARI rainfall event, to discharge with the minimum of nuisance and damage.*

(a) Assessment of effects

This criterion for overland flow and 100 year ARI capacity has been satisfied by the proposed operational water systems.

Where the alignment crosses permanent and intermittent streams, we propose a culvert, bridge or stream diversion to convey flows up to the 100 year ARI peak flow. We assessed the risks from debris flows and lesser debris blockage events using a risk-based approach and propose mitigation through measures including secondary inlets, additional culvert capacity and debris racks upstream of culvert entry.

All wetlands will be designed so that local overland flow will be diverted away from the wetland and, as noted in Section 3.1.3, each wetland is off-line. Additional clean water cut-off drains will be constructed above the alignment to prevent overland flow from entering the Project.

Overall, we consider the effects of the Project on overland flow to be minor, apart from flooding in the Carran Road Sector that is assessed in Section 8.6. We consider that it would be appropriate for a consent condition requiring design for culverts, bridges or stream diversions to pass or convey the 100 year ARI rainfall event, with consideration given to managing the risks of blockage with mitigation in design.

8.3 Stormwater quality

8.3.1 Water quality treatment

For our assessment of water quality treatment, our criteria and considerations (as discussed in Section 5.5) are:

i. *Appropriate management of run-off from land-uses with a high contaminant generation potential;*

ii. *Discharges to be treated to remove at least 75% of TSS (TSS) loads on an average annual basis (ARP: ALW);*

iii. *Consider water treatment devices that will filter litter, floatables and silt particle;*

iv. *Consider toxic, persistent or bioaccumulative contaminants that would be detrimental to the receiving environment and the selection of water treatment devices to remove contaminants;*

v. *RMA Section 7(f). Maintenance and enhancement of the quality of the environment; and* *vi. Have regard to the nature of the discharge and the sensitivity of the receiving environment to adverse effects (RMA S105).*

(a) Assessment of effects

Water quality treatment

To satisfy **Criteria (i), (ii), (iii)** and **(iv),** we propose wetlands as the preferred water quality treatment device. Refer Section 7.3.

To satisfy Criterion (i) the Project will treat runoff from all new impervious areas including the motorway surface and rock cuts. Refer Section 7.3.

In accordance with Criterion (ii) the wetlands will be designed to remove at least 75% of TSS loads on an average annual basis. They will filter litter, floatables and silt particles (Criterion (iii)) and remove metals and petroleum products (Criterion (iv)). The wetland will be designed in accordance with TP10 design guidelines. Wetlands were selected using a BPO approach and are preferred over ponds due to their better performance at contaminant removal and for temperature control. An assessment of wetland planting requirements is included in Section 8.5.1.

With respect to water quality treatment of ancillary roads, the use of vegetated roadside drains is the BPO and Criteria (i) to (vi) are satisfied. Refer Section 7.3.

Contaminant loads

We assessed **Criteria (iv), (v)** and **(vi)** using contaminant load modelling (CLM). We used CLM to assess the change in TSS, Zn, Cu and TPH load arising from the Project compared to existingvolumes in 2031. The treatment will be provided by the proposed constructed wetlands. Table 27 and Table 28 illustrate the predicted relative change in contaminant loads in the baseline pre-development and post-development scenarios for the Mahurangi and Pūhoi catchments.

The contaminant loads relate only to the urban and impervious parts of the Pūhoi and Mahurangi catchments. The impervious parts of the catchments are expected to contribute the greatest loads of metals and TPH. However, the TSS load from the rural parts of the catchment will be significant. We consider the loads relative rather than absolute estimates i.e. the loads express the relative difference between the pre-development baseline and the post-development with the Project including treatment scenarios, and not the complete load of contaminants arising from all land-uses in the entire catchment.

Table 27 shows the relative change in contaminants in the Mahurangi catchment is small, with small improvements predicted for TPH and TSS.

Table 28 shows increases in all contaminants except Zn are very low. The Pūhoi catchment has very little urban development at present, with the exception of SH1. Therefore the background levels for Zn, Cu and TPH are relatively low.

The 12% increase in Zn is related to the Pūhoi sector of the motorway having the greatest predicted number of vehicles per day. It is also related to the vegetated roadside drains that serve sections of SH1 in the existing environment, providing a greater level of Zn treatment than is assumed for the constructed wetlands that are proposed for the Project.

The absolute increase in Zn predicted in the Pūhoi catchment is 4.2 kg/year. This increase in Zn compares with the predicted increase of 5.8 kg/year of Zn in the Mahurangi. The percentage increase in the Mahurangi is only 1.3% and the reason for this is that the background load in the Mahurangi is larger pre-development.

In subsequent sections the effect of the contaminant loads on sediment and water quality is assessed.

Table 27: CLM predicted relative change in contaminated loads in the Mahurangi River catchment at 2031

Treatment Device	Average Annual Total Load (kg/year)			
	TSS	Zn	Cu	TPH
Pre-development	149,280	453.4	48.4	571.1
Post-development, with treatment	148,149	459.2	48.8	564.1
Change	-1,131	5.8	0.4	-7.0
Percentage change	-0.8%	1.3%	0.8%	-1.2%

Table 28: CLM predicted relative change in contaminated loads in the Pūhoi River catchment at 2031

Treatment Device	Average Annual Total Load (kg/year)			
	TSS	Zn	Cu	TPH
Pre-development	105,178	34.8	8.8	321.5
Post-development, with treatment	104,733	39	9.0	328.5
Change	-445	4.2	0.2	7
Percentage change	-0.4%	12.1%	1.7%	2.2%

(i) Predicted change in marine sediment quality

To assess the effect of the change in contaminant load on sediment quality, we assessed the predicted change in contaminants against Criteria (iv), (v) and (vi). The quality of existing sediments in the Pūhoi and Mahurangi harbours is good, with the exception of the upper estuary of the Mahurangi, where Copper was detected in the 63µm fraction in the amber ERC range at Vialls

Landing and Jamiesons Bay, and above the ERC red and the ISQG-low thresholds. We consider that the metals found in sediment within the upper Mahurangi are likely to be attributed to historic and existing boat related activities, rather than solely stormwater runoff.

The fate of the contaminants is discussed in this section. Moore (2009) indicates that for motorway runoff, on average 55% of the total Cu and 69% of the total Zn was in the particulate phase. Some of contaminants in the dissolved phase may be adsorbed to sediments and be deposited within the harbours, however most of the metals in the dissolved phase are likely to be diluted within the marine environment and flushed from the Pūhoi and Mahurangi harbours. The flushing time of the Pūhoi harbour is estimated as 4.6 tidal cycles and 3.7 tidal cycles for the Mahurangi (eCoast, 2013).

As discussed in the Construction Water Assessment Report, approximately 50% of sediment generated in the catchment, including sediment in road runoff, is expected to be deposited in the freshwater environments of the Mahurangi and Pūhoi. Sediment deposited in streams will ultimately be transported to the marine environments.

A proportion of the contaminants generated by the Project will be deposited in the Mahurangi and Pūhoi estuaries. Oldman et al. (2009) suggest that 80% of the sediment entering the Mahurangi harbour is deposited in the harbour with the majority of sediment deposited in the upper estuary. We undertook harbour modelling for the Project on the Mahurangi as described in Water Assessment Factual Report 5: Coastal Processes Modelling Report. Our modelling supports the conclusions of Oldman et al. (2009) in that deposition will be mainly in the upper part of the estuary. Our harbour modelling undertaken for the Project on the Pūhoi, estimates that approximately 60-70% of sediment is deposited within the Pūhoi harbour.

We expect that the changes to marine sediment quality will be minor due to the following:

- Existing sediment quality is good (except upper estuary of the Mahurangi);
- Contaminant load from the Project is small, as predicted by the CLM; and
- The harbours retain 70-80% of sediments from catchments with 20-30% being flushed to the ocean.

Therefore the contaminant load from the Project will have a minor impact on sediment quality. The effect of the predicted minor change in sediment quality on marine ecology is assessed in the Marine Ecology Assessment Report.

(ii) Contaminant concentrations in water

We assessed **Criteria (iv), (v)** and **(vi)** using contaminant concentration calculations. Existing water quality assessments presented in this section are based on long term water quality data from Auckland Council (sites Mahurangi at FHQ and Mahurangi at WTP) and grab sample data (sites MW, P10, PL, Mahurangi mouth, Pūhoi mouth) collected as part of this assessment. Water Assessment Factual Report 4: Water Quality Monitoring Report describes these data sets. The existing water quality estimates used for this assessment were calculated from the median of the monitoring results.

The data collected as part of this Project was collected in autumn 2013, and in the case of the river mouths only one event was sampled. Water quality may vary significantly in response to rainfall events and over seasons, and therefore the results based on the grab samples are not as robust as the results based on the long-term data for the two Auckland Council sites. We intend the short-term monitoring data summarised in this report to be used in conjunction with Auckland Council data as an indicator to where a water quality problem may exist.

We compared the existing baseline water quality and predicted post-development with treatment metal concentrations to the ANZECC (2000) guideline trigger values for the 95% level of species protection in freshwater for slightly-to-moderately disturbed ecosystems. We adjusted the trigger to account for water hardness (moderate hardness category). The ANZEC trigger levels in freshwater are 0.0163 mg/L for zinc and 0.0028 mg/L for copper. At the river mouths total zinc and total copper are graphed because the particulate fraction may affect marine sediment quality. In marine water the trigger levels are 0.0150 mg/L for zinc and 0.013 mg/L for copper. The ANZECC trigger values are generally accepted as low-risk ecological trigger levels.

Freshwater dissolved metal species are the most bio-available fraction and are considered the most important in assessing the effects of metal toxicity on aquatic organisms. This report presents the dissolved results compared against the ANZECC (2000) trigger values described above. The results for total zinc and total copper are included in Water Assessment Factual Report 11: Motorway Runoff Report.

The water quality results illustrated in Figure 39 to Figure 45 are for TSS and total and dissolved Zn and Cu at the water quality sampling locations.

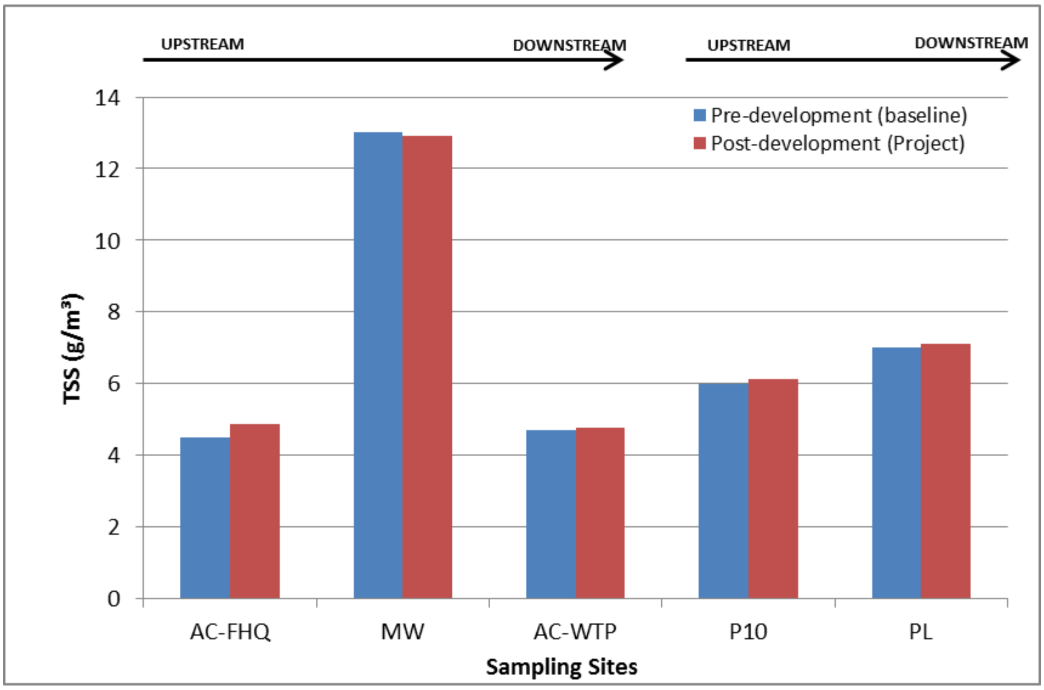

Figure 39: Total suspended solids predicted for the five water quality sites for 2013

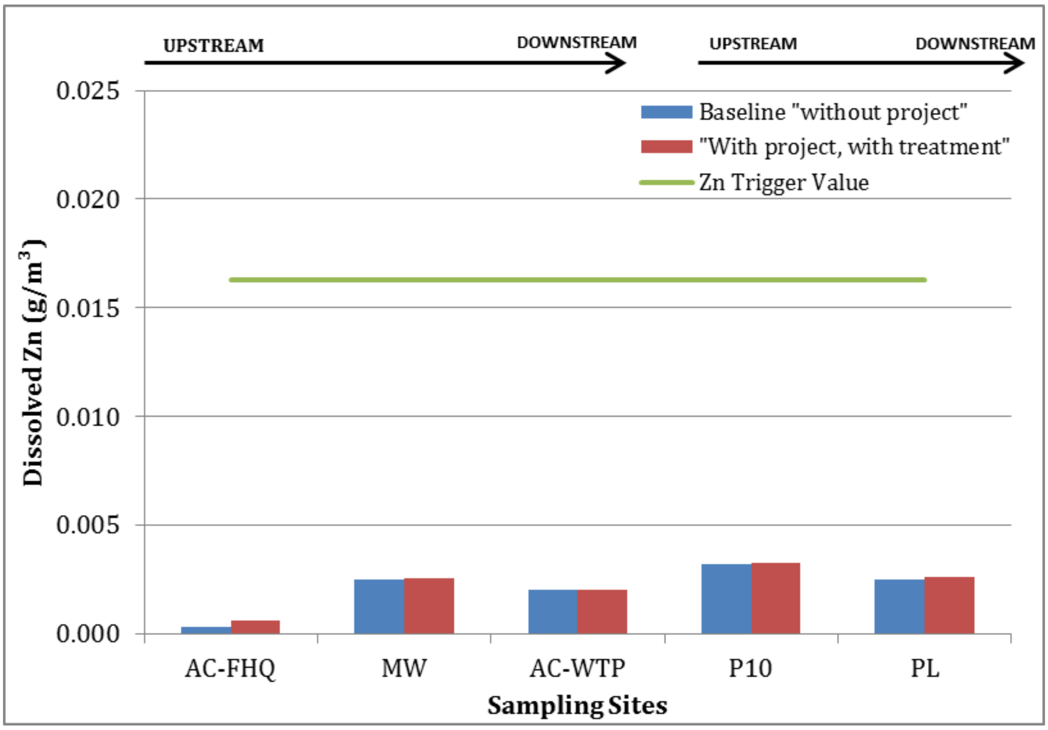

Figure 40: Dissolved zinc concentrations predicted for the five water quality sites for 2013

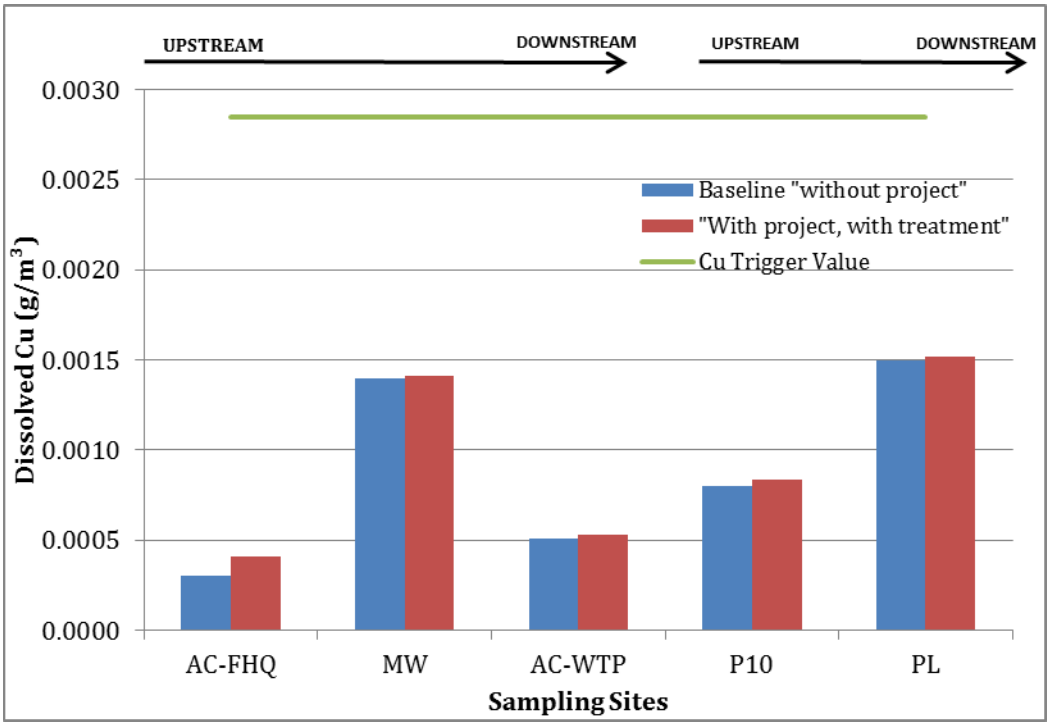

Figure 41: Dissolved Copper concentrations predicted for the five water quality sites for 2013

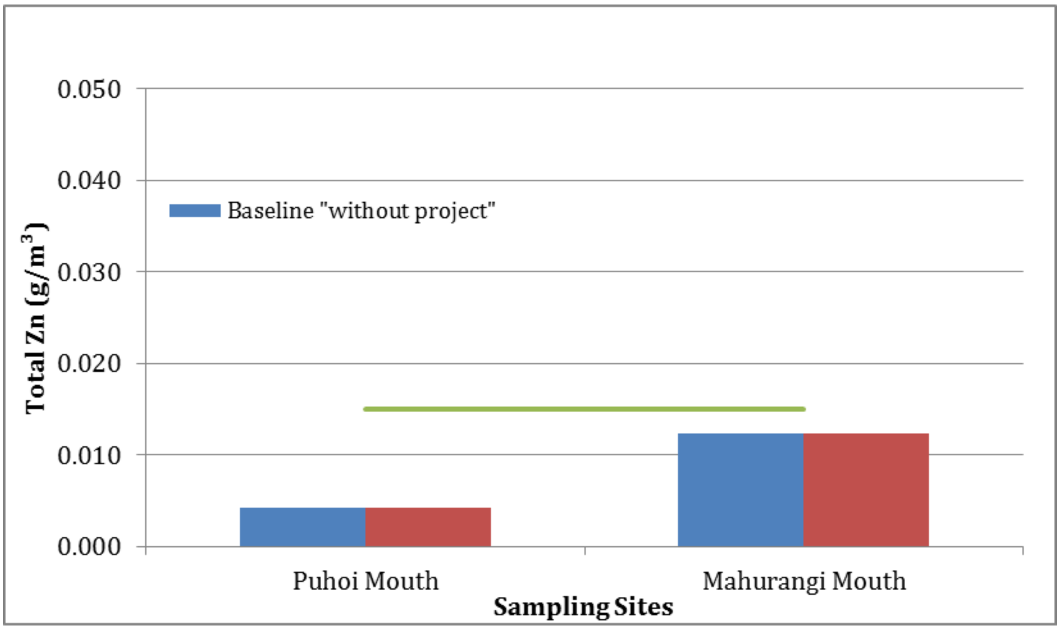

Figure 42: Total zinc concentrations predicted at river mouths for 2013

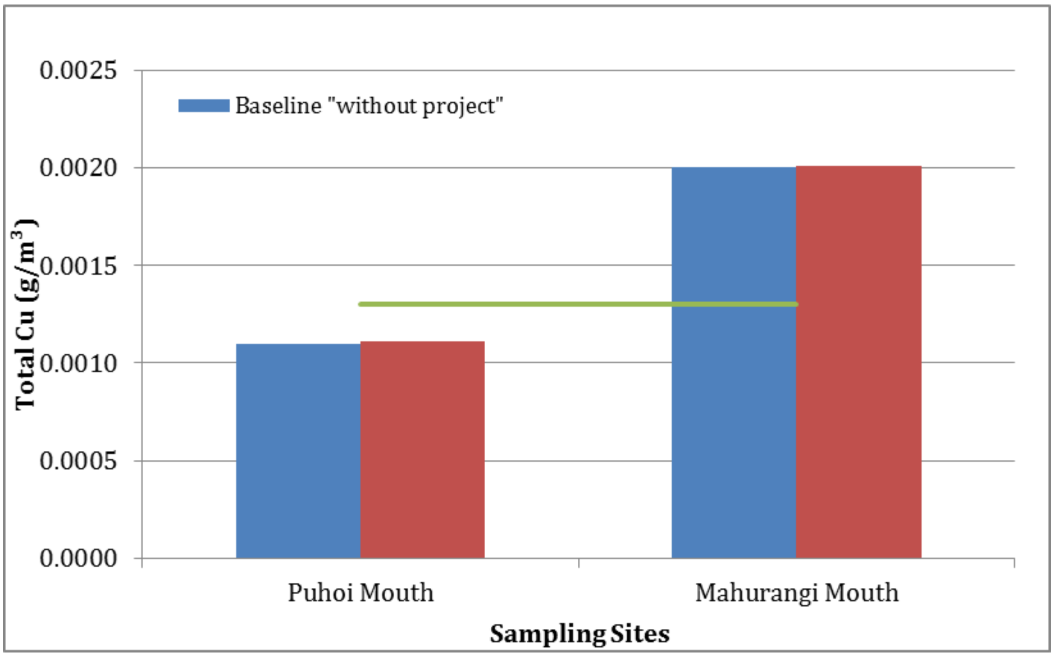

Figure 43: Total copper concentrations predicted at river mouths for 2013

We consider the existing water quality at all the freshwater sites to be good, with metals and contaminants well below the ecological trigger values. At the river mouths, the Mahurangi has elevated copper compared with the marine ecology trigger.

With the increase in contaminants associated with motorway runoff added, contaminant levels will increase at all sites. The largest proportional increases occur in the catchments where the road footprint makes up a larger proportion of the overall catchment. At the river mouths, the predicted increase in copper and zinc is very small and only a minor change in sediment concentrations is expected in those parts of the estuaries where contaminants sourced from road runoff are likely to deposit.

With the wetland treatment accounted for, the predicted water quality levels for total and dissolved Cu and Zn are well below all the freshwater quality guidelines values.

(b) Summary of water quality treatment

Overall we consider the proposed constructed wetlands are an appropriate method for managing the stormwater runoff from the Project. We consider the wetlands will treat the contaminants of concern effectively, including toxic, persistent and bioaccumulative contaminants, and with consideration of the sensitivity of the receiving environments. We consider the Project with the proposed mitigation in place, will maintain acceptable water quality.

We consider that it would be appropriate for a consent condition requiring water quality treatment to remove at least 75% of TSS loads on an average annual basis in accordance with TP10 guidelines be sought, recognising that a design to this standard will also treat toxic, persistent and bioaccumulative contaminants.

In order to maintain this level of treatment throughout the life of the Project we recommend a further condition requiring ongoing maintenance of the stormwater treatment devices.

8.3.2 Aesthetics and odour

For our assessment of aesthetics and odour, our criteria and considerations (discussed in Section 5.5) are:

- *After reasonable mixing, the contaminant or water discharged shall not give rise to any of the following effects in the receiving waters (RMA S107):*

    i. Conspicuous oil or grease films, scums or foams, or floatable or suspended materials;

    ii. Any conspicuous change in the colour or visual clarity; and

    iii. Any emission of objectionable odour.

(a) Assessment of effects

(i) Oil and Grease films

Criterion (i) with respect to oil and grease films is satisfied by the following assessment. In the existing situation, no oil or grease films were observed during the monitoring undertaken in the freshwater receiving environments for the Project

Wetland outlets will have submerged or baffled outlets for low flows so that floatables can be trapped at the main outlet. We consider the proposed wetland treatment devices will remove 60% of TPH and with TPH, most oil and grease. There may occasionally be small films occur downstream of discharge points. These small areas of film would be temporary and be dispersed and votalised, therefore we consider the adverse effects of these areas of film to be negligible.

(ii) Foams and scums

Criterion (i) with respect to foams and scums, which can be caused by algal blooms, is satisfied by the following assessment.

In the existing situation, no foams and scums were observed during monitoring undertaken for the Project in the freshwater receiving environments. We observed algal blooms in stormwater ponds on the NGTR. The algal blooms are contained within the wetlands by baffled outlets. The algal blooms present a maintenance issue as the biomass increases the sediment volume for disposal and therefore the wetlands require more frequent cleaning out.

Stormwater ponds can cause an increase in water temperature (Kelly, 2010). Wetlands, which are proposed for the Project will have good vegetation and are less likely to result in increased temperatures due to the better shading from vegetation. The design of wetlands by including deeper zones will reduce nuisance plant growth within the wetland. Discharge volumes will be very low at times when algae will develop most. These periods of low volume are during warm summer low flow conditions hence the amount of algae and potential for scums and foams to be discharged is small. Also baffle outlets will limit discharge of algal bloom and similarly foam and scums.

The receiving streams have regular flushing with high and moderate flows. During a site visit in March 2013 after a prolonged dry period, there was some periphyton growth evident in the streams, but we did not observe foams or scums. We do not consider them vulnerable to nuisance algal growth within the Project area.

Streams within long culverts are similar to streams flowing through caves or heavy forest. The water remains cool during the day, free of algae and plants. These conditions favour many fish species native to densely forested small streams in New Zealand, similar to conditions in parts of the Project (Leong et al, 2007).

Algal blooms can develop in permanent streams where the channels are too wide for low flows, resulting in raised temperatures, and where stream grades are reduced resulting in a reduction in the frequency of flows with sufficient velocity to flush periphyton. However, these effects can be minimised by design criteria to ensure water depths and velocities are maintained, which is included in the stream diversion requirements discussed in Section 7.9.

With the proposed design and suitable maintenance regime, we consider the effect of the stormwater wetlands and permanent streamworks on the development of foams and scums in receiving freshwater to be minor.

We also anticipate no change in the risk of scums and foams associated with algal blooms in the harbours for the reasons given above for wetlands and streams. We recommend consent conditions for vegetation for shading (refer Section 8.5.1) and baffles or submerged outlets to block floatable material.

(iii) Floatable or suspended material

Criterion (i) with respect to floatable material is satisfied by the following assessment.

Road users are likely to dispose of some litter along the roadway. Litter is likely to be flushed into the stormwater system. Litter will be intercepted by the wetland forebays. Furthermore with submerged or baffled outlets for low flows, floating litter can be trapped at the main outlet. Programmed maintenance will remove litter and hence, we consider the effects of litter from the Project to be minor.

(iv) Colour and clarity

Criterion (ii) regarding colour and clarity is satisfied by the following assessment.

In the existing situation during monitoring, streams were observed in low flow conditions to be slightly turbid with a light yellow brown colour. From Auckland Council data clarity was on average low and below ANZECC guidelines. In the Mahurangi harbour, clarity is low in the upper estuary but within guideline values at the heads.

The predicted increase in contaminants released during rainfall events in the operation phase of the Project may result in a change in colour and clarity.

These effects will be temporary, and are likely to coincide with the natural change in colour and clarity that will occur due to a storm event creating runoff from non-Project areas. Although there is likely to be a lag due to the attenuation of flows in wetlands, we anticipate this increase in contaminants will have a minor effect on the receiving environment. In the smaller streams in the Project area a minor effect on colour and clarity may occur at the point of discharge from each wetland but we anticipate that these effects would be restricted to short lengths of streams due to the dilution available in them. We expect no effect on the colour and clarity of water in the lower reaches of the Mahurangi or Pūhoi, or the Harbours. In these locations, the modelling predicted no change or a small reduction in contaminants.

(v) Objectionable odour

Criterion (iii) regarding objectionable odour is satisfied by the following assessment.

Algal blooms can cause objectionable odours. We do not expect operational discharges or permanent stormwater works to contribute to the risk of these conditions developing as discussed above.

Petroleum Hydrocarbons also can cause an unpleasant odour. We anticipate the proposed wetland treatment devices will effectively remove TPH and we do not expect odour downstream of stormwater discharges.

The AMA reports no complaints or problems with odour from stormwater treatment devices on the Auckland Motorway network (pers. comms. 2011 Peter Mitchell, AMA).

(vi) Summary of aesthetics and odour

Overall, we consider the Project's potential effect on aesthetics and odour will be negligible with the following mitigation measures:

- Wetlands are used to treat operational stormwater;
- Vegetation provides some shading;
- Submerged or baffled outlets are used for low flow outlets to trap floatable material;
- Wetlands are regularly maintained to remove litter; and
- Diversion requirements to include criteria to maintain velocity to mitigate ponding and stagnant water.

8.3.3 Sediment discharge

For our assessment of sediment discharge, our criterion / consideration (discussed in Section 5.5) is:

- Avoid, remedy or mitigate permanent adverse effects on the surrounding environment from the deposit of sediment, including the effects on ecological values and physical processes within the river or stream, and the potential to cause or exacerbate erosion or deposition within river / stream or on adjacent land.

(a) Assessment of effects

On the Project we anticipate some erosion of the rock cuts proposed in Pakiri Formation, as this erosion is observed on the NGTR. To capture the sediment load from the rock cut, we propose sediment traps along the base of cut faces. The sediment traps will capture some of the sediment load close to source and reduce the sediment loads conveyed to the wetlands. Design criteria will be developed for sediment traps. Maintenance of all devices will be required. We do not anticipate that the sediment load from rock cuts will reduce the performance of stormwater wetlands or cause effects such as change in colour and clarity or increased sediment deposition in receiving watercourses.

The potential to cause or exacerbate erosion or deposition within a river or stream or on adjacent land is considered in Section 8.2.

Overall we consider the physical changes on the surrounding environment from the deposit of Project generated sediment to be minor with the mitigation measures as recommended below. The ecological effects are assessed in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

To mitigate potential physical effects on the surrounding environment from the deposit of sediment we recommend:

- Wetlands that are designed to meet TP10 design criteria for the treatment of road runoff;
- Sediment traps that are designed to capture sediment eroded off cut faces thus pre-treating runoff prior to the wetlands;

- Wetlands that are designed to include extended detention, to protect receiving environments from fluctuations in flow that can increase the risk of stream bed and channel erosion (refer Section 8.2); and
- Streamworks design criteria that incorporates channel stability to prevent increased channel erosion (refer Section 8.2).

8.4 Human impacts

8.4.1 Human health

For our assessment of human health, our criteria and considerations (discussed in Section 5.5) are:

- A regional council must not grant a water permit or discharge permit for an activity that will occur upstream of an abstraction point where the drinking water concerned meets the health quality criteria if the activity is likely to;

  i. *Introduce or increase the concentration of any determinands in the drinking water, so that, after existing treatment, it no longer meets the health quality criteria; or*

  ii. *Introduce or increase the concentration of any aesthetic determinands in the drinking water so that, after existing treatment, it contains aesthetic determinands at values exceeding the guideline values.*

  (National Environment Standard for Sources of Human Drinking Water 2007)

(a) Assessment of effects

(i) Warkworth potable water supply

In order to satisfy **Criteria (i)** and **(ii)**, we assessed the effect of the change in water quality associated with the Project on the potable water supply for Warkworth, which is currently taken from the Mahurangi River, downstream of the Project. The Project is expected to result in very small increases in sediment, sediment can impact on the treatment of water, and increased sediment will result in increased turbidity which has aesthetic effects.

The Project is expected to result in very small increases in metals. We predict that the Project will slightly increase Zn which can have aesthetic effects and Cu which can have health effects. We also analysed the predicted change in TPH and hydrocarbons may have on health and aesthetic effects (MoH 2008). There is also the potential for accidental spill of contaminants entering the Mahurangi River, for example due to an accident involving a truck.

No major bacterial sources exist on the road. Some bacteria may exist in the discharge from wetlands if the wetlands are inhabited by wildfowl. Wildfowl tend to prefer stormwater ponds to wetlands. Dense planting of wetland edges will reduce the accessibility of the wetlands to wildfowl. Wetlands may develop nuisance algal growth, but are less likely to than stormwater ponds, due to increased shading resulting in maintaining cooler water temperatures.

Watercare currently sources Warkworth's potable water supply from surface water just upstream of Warkworth town centre. Currently the surface water abstraction is the only potable supply for

Warkworth and water is also taken during high flows when turbidity is high and on occasions the water treatment plant is temporarily shut down when turbidity is too high. Stored water is used when the treatment plant is shut down. The raw water taken from the Mahurangi River is treated to meet drinking water standards.

Watercare is currently developing a bore water supply that they propose will come on-line by 2016. Therefore, during the operational phase of the Project, the Watercare surface water river abstraction is likely to be a back-up potable water supply.

The predicted increase in sediment, metals, TPH, bacteria and algae is expected to have a very minor effect on the quality of the surface water and is not expected to affect the ability of the treated water to meet NZ drinking water standard values (NZDWS 2008).

The stormwater discharges from the Project are not expected to have an effect on the quality of the proposed groundwater source of drinking water for Warkworth.

If an accidental spill occurred, it is likely that a large proportion of contaminants would be intercepted by the treatment wetlands, but some residual contaminants may be discharged to the Mahurangi River. This risk presently exists for existing SH1 therefore we consider the adverse effect on the drinking water source from an accidental spill to be minor. We recommend a condition is developed that requires NZTA to inform Watercare if a spill occurs, so Watercare is able to determine what action, if any, is required.

8.4.2 Water users

For our assessment of water users, our criteria and considerations (discussed in Section 5.5) are:

i. *Minimise effects on other water users; and*

ii. *Section 107 (f) The rendering of fresh water unsuitable for consumption by farm animals.*

(a) Assessment of effects

(i) Existing and foreseeable users

Criterion (i) regarding existing and foreseeable users is satisfied by the following assessment.

With the exception of the Watercare surface water abstraction on the Mahurangi River discussed in Section 8.4.1 above, there are no consented surface water abstractions on watercourses within the Pūhoi or Mahurangi catchments that are affected by the Project.

The permitted surface water abstraction rule in the Auckland Land Air and Water Plan allows the taking and use of no more than 5m^3/day of water from a river, stream or spring, subject to conditions. No information on permitted users is available from Auckland Council.

We are aware of the Genesis Aquaculture Fish Farm on the M19 tributary of the Mahurangi. No water take consent exists for this site. However for the purposes of this assessment we assumed surface water is taken as a permitted activity for the fish farm. The site Mahurangi at FHQ is the closest water quality site to this farm. The M19 tributary of the Mahurangi River is bridged by the Kauri Eco Viaduct at this location which minimises effects on the stream. Wetland 52200 discharges upstream of the fish farm and stormwater will be fully mixed within a short distance downstream. Our analysis indicates that with the proposed wetland treatment the water quality will meet the ANZECC water quality guidelines for freshwater aquaculture.

The change in water quality predicted in the operational phase with the proposed treatment is small and we do not anticipate any moderate or significant effects on existing or future users of the permitted water abstraction.

There are 43 marine farms consented in the Mahurangi Harbour. The operational discharges are not expected to alter the water quality compared with the ANZECC aquaculture saltwater guidelines.

Overall, we consider the effects on water users to be minor outside a reasonable mixing zone.

Cultural impacts are considered and assessed in the Cultural Assessment Report.

(ii) Amenity and recreation

Criterion (i) regarding amenity and recreation values is satisfied by the following assessment.

In the Hikauae Stream and upper reaches of the Mahurangi River there may be small changes in water clarity and colour as a result of operational discharges. These changes will be temporary, and will coincide generally with the natural discolouration in runoff and stream flows during storm events. In these locations, there is limited public access.

In the lower reaches of the Mahurangi and Pūhoi Rivers and the harbours it is anticipated that there will be no change in clarity or colour as a result of the operational discharges.

Microbiological data indicates there is some existing contamination of the Mahurangi River, with median results being slightly above alert levels. The level of contamination does affect its existing suitability for contact recreation by presenting a risk to users from the microbial contaminants.

No major bacterial sources exist on the road. Some bacteria may exist in the discharge from wetlands if the wetlands are inhabited by wildfowl. Wildfowl tend to prefer stormwater ponds to wetlands. Dense planting of wetland edges will reduce the accessibility of the wetlands to wildfowl. We do not anticipate the potential bacteria introduced to stormwater by wildfowl will change the suitability of the receiving environments for contact recreation.

Overall we consider the change in water quality associated with the Project to have minor effects on human health and amenity provided wetlands are designed to meet TP10 design criteria for the treatment of road runoff and sediment traps are used to capture sediment from rock cuts.

(iii) Consumption by farm animals

Criterion (ii) regarding the quality of water for the consumption of farm animals is satisfied. The operational discharges are not anticipated to alter the quality of water for stock drinking purposes. The predicted increases in metals associated with the road are well below stock water drinking guidelines (refer to Water Assessment Factual Report 4: Water Quality Monitoring Report).

With proposed mitigation measures in place we consider the effect of the operational road runoff on stock drinking water quality to be negligible.

8.5 Ecological effects

This section provides information that supports the ecological assessment described in the Freshwater Ecology Assessment Report.

8.5.1 Protection of aquatic ecosystems habitat

For our assessment of protection of aquatic ecosystems habitat, our criteria and considerations (as discussed in Section 5.5) are:

- Avoid remedy or mitigate significant adverse changes to ecological habitat including:
  - *i. Enabling the colonisation of a diverted river or stream by aquatic flora and fauna following the completion of stream diversion activities;*
  - *ii. Enabling the restoration or enhancement of wetlands, or areas of indigenous vegetation or the habitats of indigenous fauna in any river/stream; and*
  - *iii. Not resulting in the permanent loss of any habitat of a rare or endangered species.*

(a) Assessment of effects

(i) Stream diversion

Criterion (i) to enable the colonisation of diverted streams by aquatic flora and fauna is met by stream diversion types 1 and 2, which require recreation of aquatic and riparian habitats. In addition the design allows for fish passage. The stream diversion requirements include riparian planting 10m to 20m either side of the stream, populated with assorted species found in the Rodney Ecological District to replicate the natural planting in the area where the stream is lost. These measures will ensure colonisation of diverted streams by aquatic flora and fauna. Stream diversions have riparian planting as detailed in Drawings SW-401, SW-402 and SW-403.

We consider that consent conditions should require for stream diversions with natural stream forms and riparian habitats where the streams are permanent and supporting fish habitats.

(ii) Wetlands and indigenous vegetation

Criterion (ii) for wetland and indigenous vegetation is met by the constructed wetlands and stream diversion types 1 and 2.

Constructed wetlands for the motorway will be densely planted to maximise the treatment effectiveness. Figure 10 in Section 7.3.7 shows a typical wetland section with indicative wetland and riparian planting. The riparian planting at the constructed wetlands will be species found in the Rodney Ecological District and will include open water emerging planting, littoral zone edge planting and terrestrial bank planting. A banded bathymetry will be used to increase the wetland vegetation will be in accordance with Auckland Council and NZTA standards. Further comments on existing wetlands and constructed wetlands are found in the Freshwater Ecology Assessment

Report. We have observed that the health and density of wetlands can be an issue (refer Section 7.4.2), therefore recommend a condition of consent to ensure good wetland planting and maintenance.

(iii) Habitat for rare and endangered species

An assessment of ecological effects is undertaken in the Freshwater Ecology Assessment Report to address **criterion (iii)**. The Terrestrial Ecology Assessment Report addresses terrestrial fauna and flora.

8.5.2 Effects of piping / culverting (habitat loss)

For our assessment of the effects of piping / culverting (habitat loss), our criterion / consideration (as discussed in Section 5.5) is:

- Avoid remedy or mitigate significant adverse changes to ecological habitat including enabling the colonisation of the diverted river or stream by aquatic flora and fauna following the completion of the diversion activities.

(a) Assessment of effects

At nine locations along the alignment, bridges are proposed, which avoid creating adverse ecological effects therefore the effects at these locations are negligible, other than from bridge shading.

Loss of stream length and habitat occurs as a result of permanent streams being covered by fill or spoil sites, or where culverts are required to convey streams across the alignment. Tables 23 and 24 summarise the lengths of streams affected in the Pūhoi and Mahurangi catchments and the loss of habitat for streams classified as permanent.

An assessment of the streams affected by culverts is described in the Freshwater Ecology Assessment Report.

8.5.3 Fish passage

For our assessment r of fish passage, our criterion / consideration (as discussed in Section 5.5) is:

- Avoid remedy or mitigate significant adverse changes to ecological habitat by maintaining the passage of fish and other aquatic organisms both up and downstream.

(a) Assessment of effects

The Freshwater Ecology Assessment Report has identified and named which streams and rivers crossed by the alignment are permanent or intermittent and which of those have habitat suitable for a range of fish species. With the exception of two streams in the Carran Road Sector (ecological ref. M23a and M23b), we have provided fish passage for all permanent streams where there are fish present. Fish passage is also provided for intermittent streams where the freshwater ecologists have identified potential for fish habitat upstream.

Fish passage provided by the Project will allow for "swimming" and/or "climbing" fish species, definitions of which are described in the Freshwater Ecology Assessment Report. We developed a flow chart for determining fish passage requirements for each culvert, in accordance with Auckland Regional Council Technical Report 2009/084 Fish Passage in the Auckland Region – a synthesis of current research. This flow chart is shown in Figure 12. We propose two types of fish passage; Baffle Type and Natural Bed Type. The design criteria and a description of where each type will be applied are discussed in Section 7.7.2. We consider that these two types of fish passage are best practice and suitable for the fish species recorded at the existing streams affected. Refer to Table 3 in Section 3.4 which identifies the fish passage type we specify for each culvert for the Project.

The effectiveness of the fish passage types we propose for the Project will depend primarily on the culvert slope and velocities. Access for swimming fish will be more restricted for steeper culverts than it would be in the existing streams. Access for both swimming and climbing species will be restricted during high flows, the same as it is for the existing streams, albeit for longer durations in culverts due to higher velocities predicted. Access for climbing species is not prohibited by these fish passage types as the climbing species have the ability to climb along the wetted areas outside the flow.

The drop structure required at the upstream end of culverts 47700 and 48000 (freshwater ecology reference M23a and M23b respectively) will create a barrier to swimming fish passage. These drop structures are required because the motorway is in cut or close to the level of the existing ground, which requires a drop at the inlet to the culvert for the culvert to be located at sufficient depth under the road surface. The Project freshwater ecologists are of the opinion that these barriers to fish passage are not significant as the upstream habitats are limited in size. Their assessment of these barriers is discussed further in the Freshwater Ecology Assessment Report where it is recommended that these sites be assessed further during the design phase prior to finalising the horizontal and vertical alignment of the culverts we have proposed.

Overall, we consider the effects of the Project on fish passage will be mitigated by implementation of fish passage measures. We recommend consent conditions that require fish passage for culverts where streams are permanent and support fish habitats. An assessment of the ecological effects is described in the Freshwater Ecology Assessment Report.

8.6 Flooding

For our assessment of flooding, our criteria and considerations (as discussed in Section 5.5) are:

- Not give rise to flooding of adjacent land or exacerbate existing flooding by:
  - *i. Not increasing downstream flows and thereby worsening flooding in downstream areas;*
  - *ii. Not causing flooding of a habitable floor level in any dwelling in a 100 year ARI storm; and*
  - *iii. Not occupying flood storage volume below the 100 year ARI flood level.*

(a) Assessment of effects

Flooding is considered firstly for culverts and secondly for major flooding associated with the Mahurangi River Left Branch and major secondary flow paths in the Carran Road Sector.

(i) Proposed culverts for the motorway

Criteria (i), (ii) and **(iii)** for culverts we propose for the indicative alignment are satisfied by the following assessment.

We designed the culverts to head up in accordance with the design sizing criteria in Section 6.7.2. This design approach is standard practice to efficiently convey flow through a culvert.

The headwater extents are generally local and/or within the floodplain of the streams. The only location where 100 year ARI flood headwater extents are predicted to extend beyond the designation is at Culvert 49500. The headwater floods a major branch of the Mahurangi River for approximately 500m of stream length beyond the Project designation (measured inclusive of stream meander). There are no dwellings affected. The predicted headwater extent is contained within the floodplain of the rapid flood hazard assessment for the area outside the designation, indicating that flooding here is not made worse by the Project.

Overall we consider the effects of the Project on flooding to be minor.

Culvert headwater extents have not been assessed in fill areas (spoil disposal and landscape fill sites) as the fill extents and profiles are subject to detail design.

We consider that it would be appropriate for a consent condition to be sought to limit the increase in flood level for areas outside the designation.

(ii) Proposed upgrades to existing SH1 culverts

Criterion (i) was assessed for the existing SH1 culverts affected by the Project.

We assessed the performance of existing SH1 culverts through the Pūhoi and Hungry Creek Sectors in the hydrological model described in Section 6.2. We identified three culverts requiring upgrading because additional flow will be discharged to those streams by the Project. The performance criterion for these culverts is conveyance of the 100 year ARI flood with minimum 500mm freeboard. Post-development, the three culverts listed in Table 29 do not achieve this criterion. To mitigate this and achieve the performance criteria, we propose upgrading these three culverts by providing an additional concrete pipe. The existing pipe will remain. The twin barrel will then convey post-development flow to the same outlet location as the existing SH1 culvert. Pre and post-development scenarios for the three existing SH1 culverts are shown in Table 29.

Criterion (i) is satisfied by upgrading three existing SH1 culverts (as part of the Project) to maintain their level of performance.

Table 29: Proposed upgrades to existing SH1 culverts

Culvert	Ecological Reference	Culvert Type	Diameter or Size	Sufficient Capacity Pre-development?	Flow Increase Post-development?	Sufficient Capacity Post-development with no Mitigation?	Mitigation Proposed	Sufficient Capacity Post-development with Mitigation?
SH1 Culvert P6	P6	Concrete pipe	900mm diameter	N	Y	N	Existing culvert to remain. Construct new 1.2 m diameter concrete pipe culvert next to existing.	Y
SH1 Culvert P8	P8	Concrete pipe	1200mm diameter	Y	Y	N	Existing culvert to remain. Construct new 0.9 m diameter concrete pipe culvert next to existing.	Y
SH1 Culvert P9	P9	Concrete box culvert	2 m x 2.1 m box culvert	N	Y	N	Existing culvert to remain. Construct new 1.6 m diameter concrete pipe culvert next to existing.	Y

(iii) Flooding in the Carran Road Sector

Criteria (i), (ii) and **(iii)** are assessed for flooding in the Carran Road Sector as detailed below.

Flooding in the Carran Road Sector is a major consideration for the indicative alignment. The main floodplains are associated with the Mahurangi River Left Branch and the major secondary flow path that spills from the Mahurangi River Left Branch and flows north before returning via the Hudson Road area to the Mahurangi River downstream of Falls Road (refer Section 4.3 for details).

Our approach to avoid and mitigate flood effects is described in Section 7.10 and in particular Figure 18. Key aspects of the scheme and the potential residual effects are as follows:

- We moved the alignment of the motorway west to avoid the floodplain;
- We have provided the Woodcocks Road Viaduct (280m span) which crosses the floodplain of the Mahurangi River Left Branch, refer Drawing S-101 for details. Whilst flooding is not the sole driver for the span of this viaduct, it has been sized to accommodate the predicted floodplain extent. A key consideration for the detailed design phase is where the southern abutment of the proposed viaduct occupies a small area of the floodplain which may reduce flood conveyance; and
- We have provided Carran Road Flood Relief Bridge (60m span) to cross the major secondary flow path, refer Drawing S-111 for details. Flooding is the primary reason for the specified span of this bridge as discussed in Section 7.6. A key consideration for the detailed design phase is where the approach abutments occupy the floodplain which may reduce flood conveyance.

The differences between pre and post-development flood levels for the Carran Road Sector are shown in Figure 44, which is based on our modelling using the Auckland Council rapid flood hazard model. It shows the indicative alignment north of the Carran Road Flood Relief Bridge is located outside the floodplain. The Carran Road Flood Relief Bridge conveys the secondary flow, but there is an afflux upstream of the bridge that results in an increase in flood levels of up to 100mm. There is also an increase in flood levels of up to 100mm in the vicinity of the Woodcocks Road Viaduct. The extent of the increase in flood levels occurs along the Mahurangi River until the Falls Road area. The flood levels decrease along the secondary flow path downstream of the Carran Road Flood Relief Bridge.

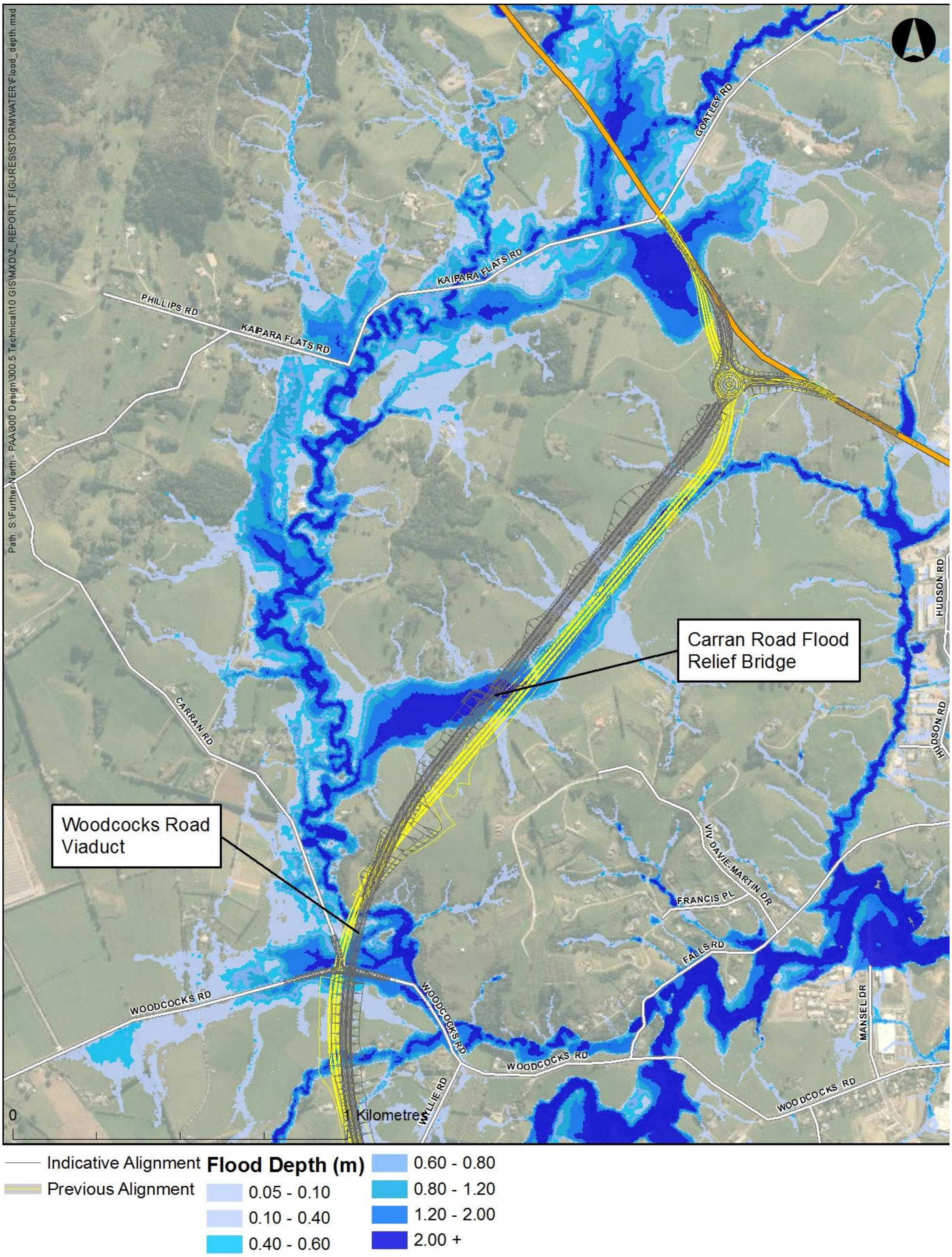

Figure 44: Carran Road Sector water level difference for 100 year ARI

The modelling predicts a slight reduction in flow into the secondary flow path downstream of the Carran Road Flood Relief Bridge. This reduction in flow is caused by the afflux upstream of the Carran Road Flood Relief Bridge, which reduces the overflow from the Mahurangi River Left Branch. A comparison of pre and post-development flow for the 100 year ARI rainfall event at the proposed Carran Road Flood Relief Bridge is shown in Figure 45.

The afflux at the upstream side of the Carran Road Flood Relief Bridge causes an increase in flow at the Woodcocks Road Viaduct in a 100 year ARI rainfall event. A comparison of pre and post-development flow for the 100 year ARI rainfall event at the proposed Woodcocks Road Viaduct is shown in Figure 46.

The peak flow at the Carran Road Flood Relief Bridge decreases by approximately $5m^3/s$, whereas the peak flow at the Woodcocks Road Viaduct increases by approximately $2m^3/s$. The increase in flow downstream of Woodcocks Road Viaduct means criterion (i) is not satisfied. However this $2m^3/s$ increase is less than 2% of the pre-development 100 year ARI rainfall event flow. We consider the effects of this increase in flow downstream of the Project to be minor.

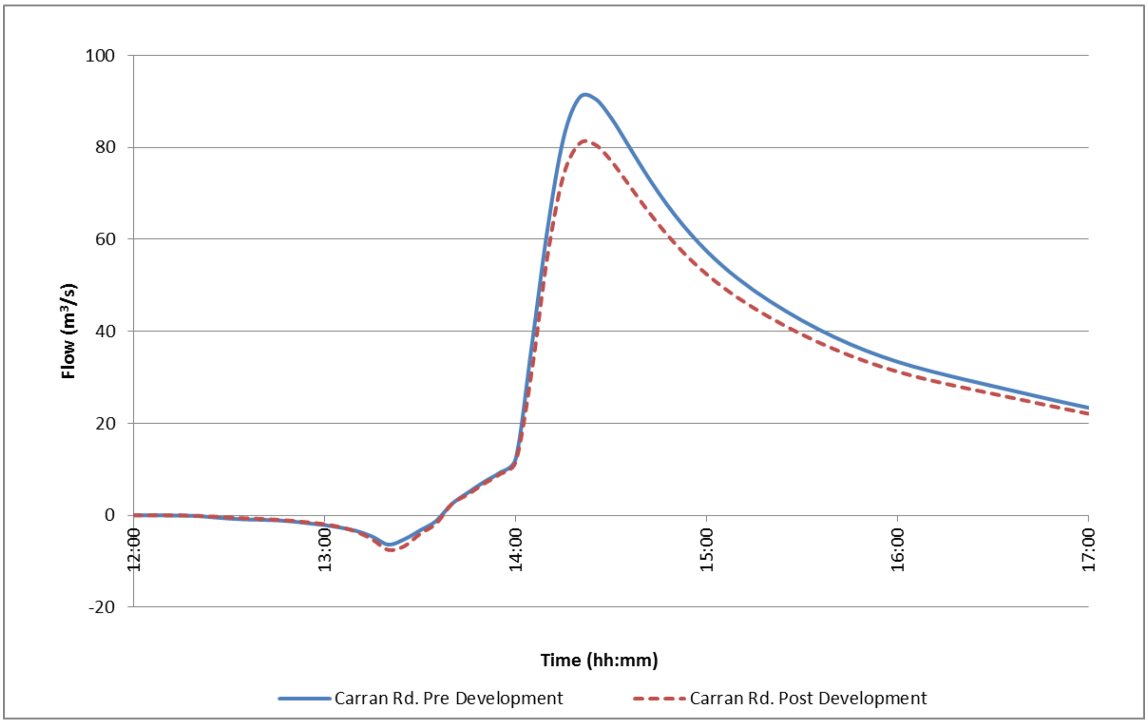

Figure 45: 60m span Carran Road Flood Relief Bridge flow differences for 100 year ARI

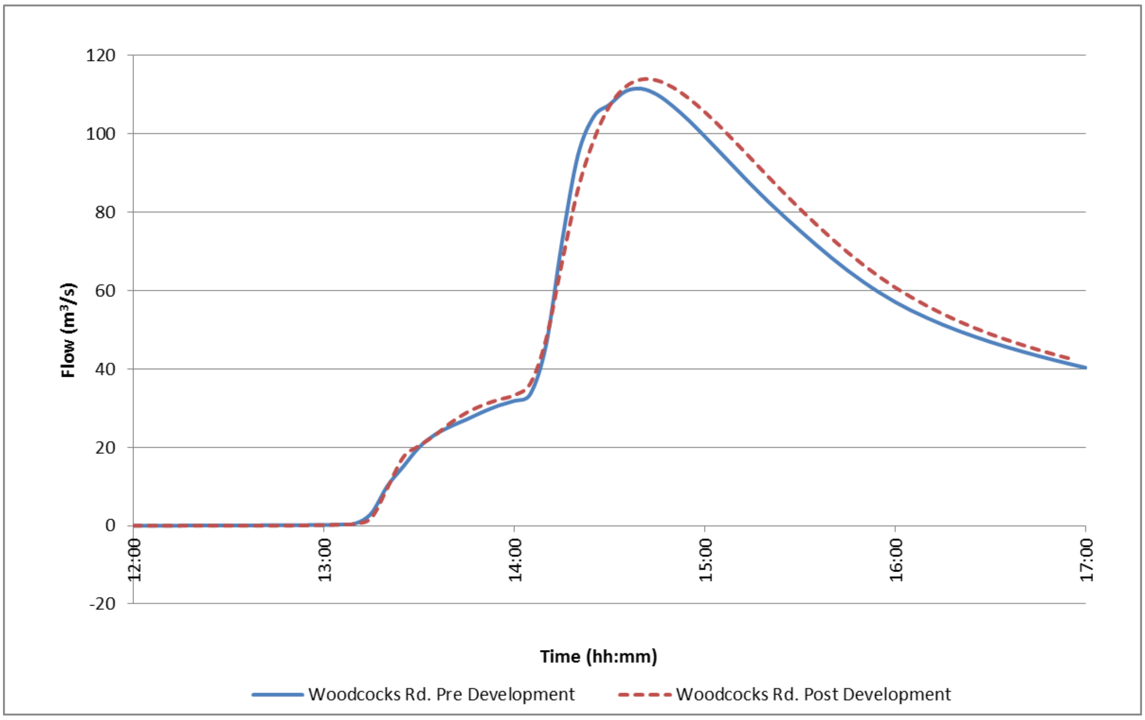

Figure 46: Woodcocks Road Viaduct flow differences for 100 year ARI

The effect of the local increase in flood levels predicted is a slight increase in the floodplain extent. More significant however is an increase in flood levels predicted at four dwellings located beyond the designation. These dwellings are shown in Figure 47 with further details in Table 30 and will be subject to a potential increase in flood level/depth ranging from approximately 30mm to 80mm as a result of the Project.

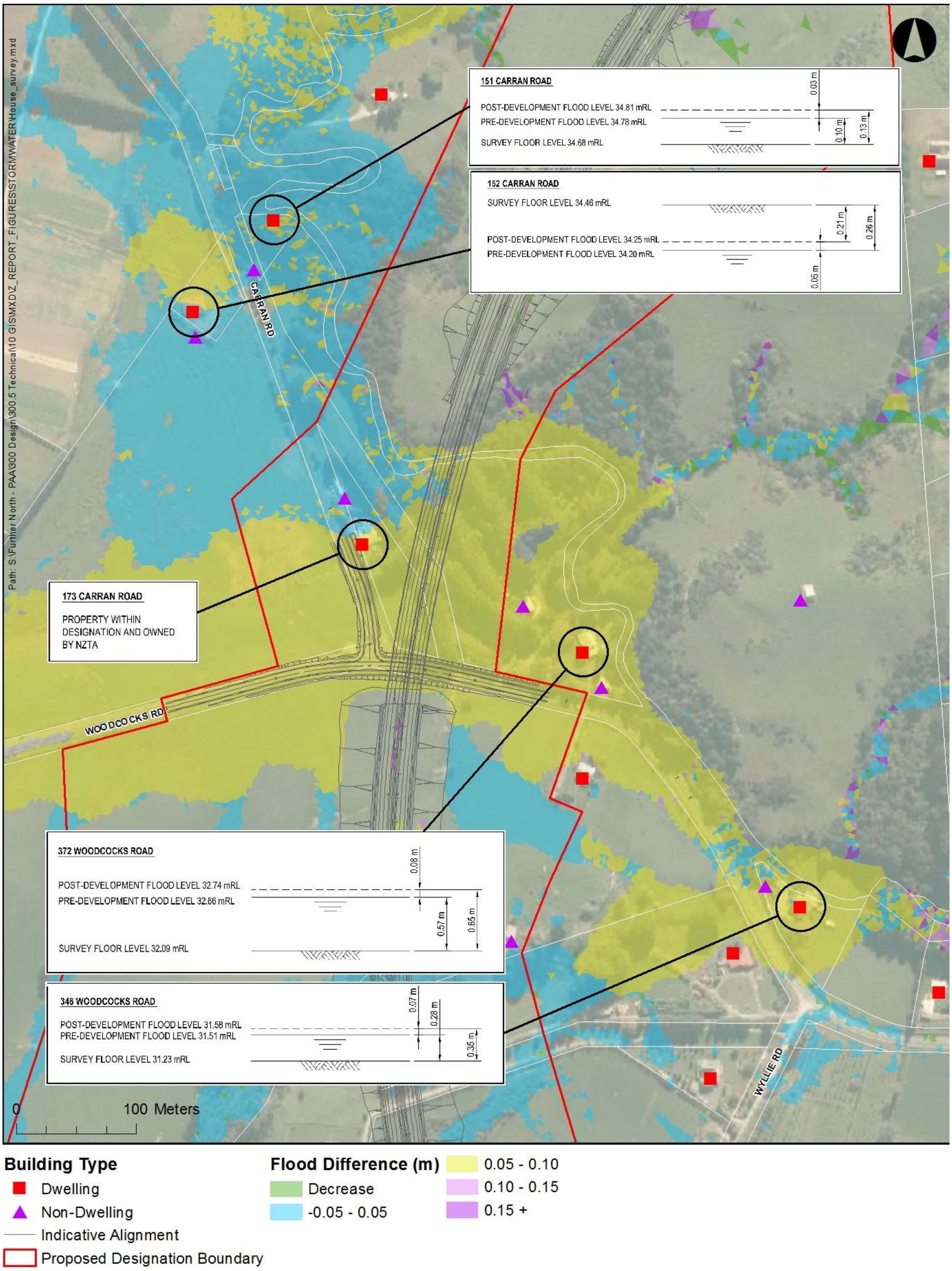

Figure 47: Dwelling floor and flood levels

Table 30: Dwellings affected by flooding in a 100 year ARI rainfall event

Street Address of Dwelling Affected	Lowest Habitable Floor Level *1 (m RL)	Pre-development Flood Level (m RL)	Existing Flood Depth (m)	Post-development Flood Level (m RL)	Pre-development Flood Level Above Floor Level (m RL)	Post-development Flood Level Above Floor Level (m RL)	Project Increase in Flood Depth (m)
151 Carran Road	34.68	34.781	1.779	34.813	0.101	0.133	0.03
152 Carran Road	34.46	34.200	0.404	34.249	-0.260 *2	-0.211 *2	0.05
346 Woodcocks Road	31.23	31.508	0.967	31.578	0.278	0.348	0.07
372 Woodcocks Road	32.09	32.661	1.510	32.736	0.571	0.646	0.08

*1 Floor level surveyed is lowest habitable floor level constructed or consented on or before Friday 28 June 2013.

*2 A (-) ve reduced level means this reduced is below the lowest habitable floor level.

The results in Table 30 show that the dwelling floor levels at No. 151 Carran Road and Nos 346 and 372 Woodcocks Road are below the pre-development flood level. The dwellings flood pre-development and the increase in flood level increases by only 30mm, 70mm and 80mm respectively post-development. We consider the effect of these increased flood levels on the dwellings at No. 151 Carran Road and Nos 346 and 372 Woodcocks Road to be moderate.

At No. 152 Carran Road, the dwelling floor level is 260mm above the pre-development flood level. The Project increases this flood level by only 50mm therefore the flood level remains 210mm below the floor level of the dwelling. We consider the effect of the increased flood level at No. 152 Carran Road to be minor.

No dwellings in the Carran Road Sector located within the predicted 100 year ARI floodplain, with a floor level above the flood level pre-development, become newly inundated by a higher flood level caused by the Project. Criterion (ii) is therefore satisfied.

There may be a slight shift in the frequency at which flood depths occur as a result of the Project i.e. the pre-development 100 year ARI flood depth will occur slightly more frequently with the Project. This change is expected to be minimal and of minor effect because the increase in flood depths are small relative to the total water depths (as measured to channel invert levels).

As noted in Section 7.10, it could be considered at the detailed design phase to improve the capacity of the secondary flow path at the northern end of the alignment which may enable the proposed Carran Road Flood Relief Bridge span to be reduced.

It has not been possible to provide an alignment that does not occupy the flood storage volume below the 100 year ARI flood level in some areas in the Carran Road Sector. Criterion (iii) is therefore not satisfied. However our BPO to mitigate the effects of occupying flood storage volume below the 100 year ARI flood level was to move the indicative alignment out of the floodplain north of the Carran Road Flood Relief Bridge, and provide sufficient cross drainage and bridges to allow the floodplain and secondary flow paths to get from one side of the alignment to the other. With our mitigation of the effects by BPO, we consider the effects of the Project occupying an area of flood storage volume below the 100 year ARI flood level to be minor.

Overall the Project has a minor to moderate effect on flooding in the Carran Road Sector due to the afflux upstream of the Carran Road Flood Relief Bridge and the increase in flood depth predicted for the four dwellings listed in Table 30. The flooding effects are partly mitigated by avoidance and mitigation measures incorporated into the Project. Further investigation during the detailed design phase will refine these mitigation measures proposed.

It would be appropriate for a consent condition requiring that a maximum change in flood level be sought for the Carran Road Sector, specifically in the vicinity of the Carran Road Flood Relief Bridge and the Woodcocks Road Viaduct. We propose a maximum change in flood level of 100mm, which we consider to be within the effects documented by this assessment.

(iv) Flooding in the Puhoi Sector

Auckland Council flood maps suggest there is flooding of dwellings within Puhoi township, refer Drawing SW-103. The proposed Puhoi Viaduct spans the floodplain and is significantly larger than the existing SH1 bridge across the river. Therefore we consider there will no effect from the Project on the existing flooding that is predicted for the Puhoi township.

9. Conclusions and recommendations

This Report provides an assessment of the environmental effects that relate to the Project's operational water systems. The operational water systems include the permanent stormwater management systems and modifications to streams/floodplains in place during the operation of the motorway.

We developed the operational water systems for the Project based on a BPO approach that considered alternatives and how to best practically minimise adverse effects on the environment.

We have assessed the effects of the Project based on the concept design that incorporates BPO measures to avoid, remedy and mitigate effects.

We have assessed the Project's effects on the environment against assessment criteria developed from the RMA, ARP: ALW and the District Plan. The assessment criteria are identified broadly as stormwater quality, stormwater quantity, human impacts, ecological impacts and flooding.

The **water quality** effects are mitigated by stormwater treatment systems that include wetlands throughout the Project and sediment traps at the base of rock cuts. We propose vegetated roadside drains for ancillary roads. Overall we consider the effects on water quality to be minor.

The **water quantity** effects are mitigated by extended detention systems in wetlands to minimise stream erosion. Overall we consider the effects from changes to water quantity to be minor.

The **human impacts** are mitigated by the stormwater treatment systems. We have considered the effects on the Warkworth potable water supply, amenity, recreation, water users and farm takes. Overall we consider the effect on humans to be minor.

The **ecological** effects are assessed in the Freshwater Ecology Assessment Report. The operational water systems include bridges over streams, culverts with fish passage and stream diversions with natural stream forms. To the extent that we can assess these matters as part of the Operational Water Assessment, these mitigation measures provide fish passage and restoration of stream habitats.

Finally, **flooding** effects are mitigated for culverts by designing culverts to convey the 100 year ARI flood. Impacts on the existing floodplain of the Mahurangi Left Branch River are avoided by changing the alignment and mitigated by the Woodcocks Road Viaduct and Carran Road Flood Relief Bridge. The residual effect includes up to 100mm of afflux upstream of these structures for the 100 year ARI flood, which affects four properties by up to an 80mm increase in flood level. We predict three dwellings that already flood to have slightly worse flooding as a result of the Project, whereas the fourth dwelling does not flood and remains unaffected by floodwater. Overall, we consider the flooding effects to be minor to moderate.

We recommend that there are consent conditions requiring:

Stormwater discharges

- Water quality treatment to remove at least 75% of TSS loads on an average annual basis and to follow TP10 guidelines, recognising that a design to this standard will also remove toxic, persistent and bioaccumulative contaminants;
- Wetlands to have forebays and submerged or baffled low flows outlets so that floatables and litter can be trapped in the wetland;
- Extended detention for all wetlands that discharge to stream environments;
- Sediment traps or alterative mitigation for sediment eroded off rock cuts;
- Vegetated roadside drains for water quality treatment for ancillary roads;
- Undertaking and documenting of operation and maintenance of stormwater treatment devices including the sediment traps;
- Erosion control for stormwater outfalls to minimise bed scour and bank erosion in receiving environments;
- The design of stormwater outfalls shall assess various rainfall and tailwater levels to ensure the critical storm is considered;
- Wetlands to have dense, healthy planting in emergent, littoral and riparian zones in designs which are maintained in operation. Vegetation to provide some shading; and
- NZTA to inform Watercare if a spill occurs on the motorway, so Watercare can take action to protect their surface water take (refer Section 8.4.1).

Stream activities

- Design for culverts or bridges or stream diversions for the 100 year ARI rainfall event, with consideration given to the risks of blockage with mitigation in design;
- Fish passage in culverts to be provided for all permanent streams and all instances where there are fish present or potential for fish habitat upstream in intermittent streams;
- Erosion control for culverts to minimise bed scour and bank erosion in receiving environments;
- Stream diversions to have natural stream forms where the diverted streams are permanent and supporting fish habitats;
- Stream diversions to be in general accordance with stream diversion requirements (Table 17) for flow, channel stability, in-stream habitat and riparian planting; and
- Monitoring over a limited post-construction period for erosion prone streams.

Flooding

- A maximum change in flood level be required for Carran Road Sector, with 100mm considered as a reasonable amount based on assessment of effects and flood risks upstream;
- Elsewhere the effects of culverts on flood levels are to be minimised beyond the designation; and

- Detailed hydrological and hydraulic modelling required at the detailed design stage for design and confirmation that effects meet current requirements.

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