TE TUPU NGĀTAHI
SUPPORTING GROWTH

Northwest Strategic Assessment of Flooding Effects

December 2022

Version 1

WAKA KOTAHI
NZ TRANSPORT AGENCY

New Zealand Government

Document Status

Responsibility	Name
Authors	Loudene Marais and Katelyn Symington
Reviewer	Mike Summerhays
Approver	John Daly

Revision Status

Version	Date	Reason for Issue
1	16/12/2022	Notice of Requirement Lodgement

Table of Contents

Appendices

Table of Figures

Table of Tables

Glossary of Acronyms / Terms

Abbreviations	Description
AC	Auckland Council
AEE	Assessment of Effects on the Environment
ARI	Average Recurrence Interval of a rainfall event
ASH	Alternative State Highway
AT	Auckland Transport
AUP: OP	Auckland Unitary Plan Operative in Part
BCI	Brigham Creek Interchange
CC	Climate change
CC2W	City Centre to Westgate
CEMP	Construction Environmental Management Plan
FTN	Frequent Transit Network
FULSS	Future Urban Land Supply Strategy
FUZ	Future Urban Zone
Ha	Hectares which is used for catchment areas
MfE	Ministry of the Environment
MPD	Maximum Probable Development based on zonings as permitted under AUP:OP
NAL	North Auckland Line Railway
NoR	Notice of Requirement (under the Resource Management Act 1991)
Package	Strategic Assessment Package
Projects	Projects within the Strategic Assessment Package include: • Alternative State Highway (ASH), including Brigham Creek Interchange (BCI) • the Rapid Transit Corridor (**RTC**), including the Regional Active Mode Corridor (RAMC) • State Highway 16 (SH16) Main Road Upgrade • Two RTC Stations, located at Kumeū and Huapai • The upgrade of Access Road local arterial corridor
RCP	MfE Representative Concentration Pathways
RMA	Resource Management Act 1991
RTC	Rapid Transit Corridor
RAMC	Regional Active Mode Corridor
RL	Reduced level

Abbreviations	Description
RUB	Rural Urban Boundary
SGA	Te Tupu Ngātahi Supporting Growth Alliance
SH16	State Highway 16
The Council	Auckland Council
Waka Kotahi	Waka Kotahi NZ Transport Agency

1 Executive Summary

This report provides an assessment of flood effects associated with the construction, operation and maintenance of the Projects that comprise the Strategic Assessment Package. The Projects are shown on Figure 1-1 below.

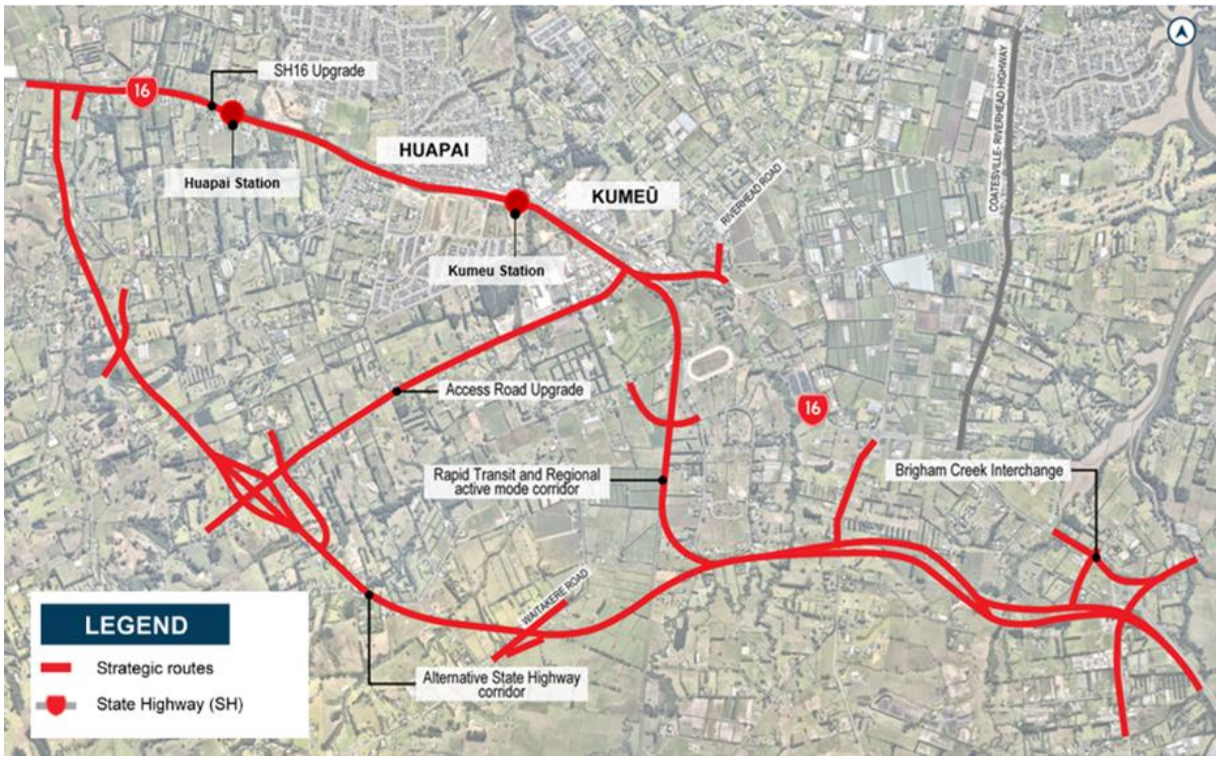

Figure 1-1: Location of the projects in the Strategic Assessment Package

Flooding is a natural hazard and has therefore been considered as part of the Strategic Package Notices of Requirement. The works required for the Strategic Package have the potential to lead to flooding effects and an assessment of predicted flood effects is provided to demonstrate that these effects can be appropriately controlled in the future. It is also acknowledged that there will be a subsequent process for seeking regional resource consents which will address a wider range of potential stormwater quantity and quality effects.

In the context of this assessment, flood hazard effects may include changes to:

- the flood freeboard to existing habitable buildings, overland flow paths,
- the ability to access property by residents and emergency vehicles,
- the level of flooding to roads and flooding arising from the blockage of stormwater drainage.
- the effects considered relate to existing habitable buildings / infrastructure and potential future effects on upstream and downstream properties.

Methodology

The assessment of flooding effects for the Northwest Strategic Package has involved the following steps:

- Desktop assessment to identify potential flooding locations from Auckland Council Geomaps.

- Modelling of the pre-development and post-development terrain with Maximum Probable Development (MPD) and 100yr Average Recurrence Interval (ARI) plus climate change rainfall.
- Two climate scenarios were modelled, one allowing for 2.1 °C of temperature increase and one for 3.8 °C of temperature increase. The higher climate change scenario has been used to undertake a sensitivity analysis.
- Producing flood level maps for pre-development and post-development scenarios and flood difference maps to show the change in flood levels and extents as a result of the Project.
- Review of flood difference maps at key locations such as bridges and where there are noticeable changes in flood extents or flood levels to understand the reason for the change and potential future opportunities to reduce the effects

While stormwater effects apart from flooding are not assessed, provision is made for the future mitigation of potential stormwater effects (stormwater quantity, stormwater quality and instream structures) by identifying the space required for stormwater management devices (for example drainage channels and ponds) and incorporating land for that purpose into the proposed designation boundaries. These devices have been designed to attenuate the 100year ARI using 10% of the total impervious road catchment area in accordance with Auckland Council and Waka Kotahi guidance[1,2]. Note for existing roads being widened this allows for greater impervious road area being treated than the widened road area alone.

Flooding effects will be subject to further verification at a detailed design stage to ensure compliance with conditions. It is expected that coordination and integration of the corridor design with future urban zone (FUZ) development will be undertaken to confirm and address potential future adverse effects.

Positive Effects

There is the potential for positive effects associated with the projects. These include where new bridges are proposed which raise the existing road levels reducing the potential for flood levels to overtop the road and reducing flood hazard. Additional positive effects can be realised through upgrades to existing culverts or new culvert crossings to improve flow under the proposed project corridor. The scale of these effects will be confirmed at detailed design stage. Water quality treatment allowances will result in improved environmental outcomes as the total road area, and not just the additional road area, for existing roads have been included for treatment.

Construction phase effects

The potential construction flooding effects can be appropriately managed with the measures set out in Section 7.1. It is expected that construction works can be carried out in a way that will appropriately manage the risk. Flood risk mitigation measures will be captured in the Construction Environmental Management Plan (CEMP) and it is recommended this be included as a condition of the proposed designation.

Operational phase effects

NoR S1: Alternative State Highway (ASH), including Brigham Creek Interchange (BCI)

The assessment of operational effects found negligible to moderate flood effects during the operational phase of the corridor. There is space within the designation to mitigate this risk by

[1] Auckland Council's Stormwater Management Devices in the Auckland Region, Guideline Document 2017/001 (December 2017)
[2] Waka Kotahi NZTA's Stormwater Design Philosophy Statement (May 2010)

potentially providing overland flow paths or secondary inlets which can be addressed at the detailed design stage. A range of potential mitigation measures for operational effects have been set out in Section 8.1 and it is anticipated the most appropriate mitigation will be identified and will form part of detailed design.

Potential flooding effects will be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in this Report.

NoR S2: SH16 Main Road Upgrade

The assessment of operational effects found negligible to moderate flood effects during the operational phase of the corridor. A range of mitigation measures which might be implemented for operational effects have been set out in Section 8.1. There is space within the designation to mitigate this risk by providing new or upsized crossings with the aim of achieving flood neutrality which can be addressed at the detailed design stage.

Potential flooding effects can be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in this Report.

NoR S3: Rapid Transit Corridor (RTC), including the Regional Active Mode Corridor (RAMC)

The assessment of operational effects found minor to moderate flood effects during the operational phase of the corridor. There is space within the designation to mitigate this risk by providing overland flow paths or secondary inlets which can be addressed at the detailed design stage. A range of potential mitigation measures for operational effects have been set out in Section 8.1 and it is anticipated the most appropriate mitigation will be identified and will form part of detailed design.

There was a moderate effect to flooding at properties along the RAMC. Several wetlands are proposed within the flood plain. For these wetlands potential mitigation could include raising the embankment and installing diversion drains for the overland flow path.

Potential flooding effects will be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in this Report.

NoR S4: Access Road Upgrade

There was a moderate effect as a result of increased flood levels at open space along the Access Road corridor. This effect could be mitigated by designing, installing and maintaining diversion drains alongside road to discharge into culvert crossing at Waitakere Rd. Mitigation will be finalised as part of detailed design.

Potential flooding effects will be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in this Report.

Sensitivity Analysis

A sensitivity analysis has been undertaken to consider the effects of additional rainfall under a more severe climate change scenario (3.8° temperature increase compared to the standard 2.1° temperature increase). The sensitivity analysis identified an increased risk of flooding at some locations. However, this increased risk can be addressed through the mitigation measures described in the report.

Conclusion

There may be some temporary construction phase flooding risk associated with temporary works required for the construction of culverts and stormwater management infrastructure. However, the details of the construction approach will be confirmed at detailed design.

It is expected that construction works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the CEMP. Flood hazard has been identified as a matter to be addressed in the CEMP and included as a condition of the proposed designation.

Potential operational effects include increased flood water levels upstream and downstream of crossings and bridges. Effects were assessed as negligible to moderate. Operational impacts will likely be resolved during detailed design by optimising the design of culverts and bridges to minimise flood effects upstream and downstream of crossings. Potential flooding effects will be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in this Report.

2 Introduction

This flooding assessment has been prepared for the Northwest Strategic Projects and Kumeū Huapai Local Arterials Notices of Requirement (**NoRs**) for Waka Kotahi NZ Transport Agency (**Waka Kotahi**) and Auckland Transport (**AT**) (the "**Strategic Assessment Package**"). The NoRs are to designate land for future strategic and local arterial transport corridors as part of Te Tupu Ngātahi Supporting Growth Programme (**Te Tupu Ngātahi**) to enable the construction, operation and maintenance of transport infrastructure in the Northwest area of Auckland.

The Strategic Assessment Package will provide route protection for the strategic projects, which include:

- Alternative State Highway (ASH), including Brigham Creek Interchange (BCI)
- the Rapid Transit Corridor (**RTC**), including the Regional Active Mode Corridor (RAMC)
- State Highway 16 (SH16) Main Road Upgrade
- Two RTC Stations, located at Kumeū and Huapai
- The upgrade of Access Road local arterial corridor

This report assesses the flooding effects of the Northwest Strategic Assessment Package identified in Figure 4-1 and Table 2-1 below.

Refer to the main AEE for a more detailed project description.

Table 2-1: Northwest Strategic Assessment Package – Notices of Requirement and Projects

Notice	Project
NoR S1	Alternative State Highway (ASH), including Brigham Creek Interchange (BCI)
NoR S2	SH16 Main Road Upgrade
NoR S3	Rapid Transit Corridor (**RTC**), including the Regional Active Mode Corridor (**RAMC**)
NoR S4	Access Road Upgrade
NoR HS	Huapai RTC Station
NoR KS	Kumeū RTC Station

2.1 Purpose and Scope of this Report

This assessment forms part of a suite of technical reports prepared to support the assessment of effects within the Strategic Assessment Package. Its purpose is to inform the AEE that accompanies the Strategic Assessment Package sought by Waka Kotahi and AT.

This report considers the actual and potential effects associated with the construction, operation and maintenance of the Strategic Assessment Package on the existing and likely future environment as it relates to flooding effects and recommends measures that may be implemented to avoid, remedy and / or mitigate these effects.

The key matters addressed in this report are as follows:

a) Identify and describe the stormwater context of the Strategic Assessment Package area;
b) Identify and describe the potential flooding effects of each Project corridor within the Strategic Assessment Package;
c) Recommend measures as appropriate to avoid, remedy or mitigate potential flooding effects (including any conditions/management plan required) for each Project corridor within the Strategic Assessment Package; and
d) Present an overall conclusion of the level of potential flooding effects for each Project corridor within the Strategic Assessment Package after recommended measures are implemented.

This report draws a distinction between stormwater effects and flood hazard effects, which are a subset of potential stormwater effects.

Stormwater effects are broadly divided into:

- Quantity effects (such as flooding, erosion and changes to hydrology - which may cause effects on stream habitat, baseflow and sediment movement in streams),
- Quality (including the discharge of contaminants – which may cause effects on aquatic fauna, public health and amenity values) and the effects on streams due to the presence of in-stream structures.

These effects are considered through RMA section 13, 14 and 15 consents and are administered by regional councils (or, in the case of Auckland, as regional consents by the Auckland Council as a Unitary Authority).

Provision is made for the future management of the stormwater effects (stormwater quantity, stormwater quality and instream structures) by identifying the space required for stormwater management devices (for example drainage channels and wetlands) and incorporating land for that purpose into the NoRs. In identifying the land required for these devices, preliminary sizing and siting has been undertaken and offset allowances made for construction phase works.

The designation is a land use or district planning mechanism. Hence, the assessment of effects has been limited to flood hazard matters as they are the only matters that would trigger a District Plan consent requirement under the AUP:OP. In presenting information on flood hazard effects, it is therefore acknowledged that there will be a subsequent process for seeking regional council consents.

Flood hazard effects include changes to; the flood freeboard to buildings, the depth of flooding on property, the creation of new overland flow paths, the ability to access property by residents and emergency vehicles and potential flood prone areas caused by blockage of culverts.

2.2 Report Structure

The report is structured as follows:

a) Overview of the methodology used to undertake the assessment and identification of the assessment criteria and any relevant standards or guidelines;
b) Description of each Project corridor and project features within the Strategic Assessment Package as it relates to stormwater;
c) Identification and description of the existing and likely future flooding environment;
d) Description of the potential positive effects of the Project;

e) Description of the potential adverse flooding effects of construction of the Project;
f) Description of the potential adverse flooding effects of operation of the Project;
g) Recommended measures to avoid, remedy or mitigate potential adverse flooding effects; and
h) Overall conclusion of the level of potential adverse flooding effects of the Project after recommended measures are implemented.

This report should be read alongside the AEE, which contains further details on the history and context of the Project. The AEE also contains a detailed description of works to be authorised for the Project, likely staging and the typical construction methodologies that will be used to implement this work. These have been reviewed by the author of this report and have been considered as part of this assessment of flooding effects. As such, they are not repeated here, unless a description of an activity is necessary to understand the potential effects, then it has been included in this report for clarity.

2.3 Preparation for this Report

In preparation of this report several resources were used to support the assessment. These included technical specialist inputs, previous reports, catchment flood models and team workshops.

The AUP:OP was used to identify the existing and likely future environment. Information from the Project Team and SGA Redhills and Kumeū models were used to assess the flood water levels and extents of the existing (pre-development) terrain.

It should be noted the existing terrain has been used for flood modelling of the pre-development and post-development scenarios as there is no information about what future landforms will take.

3 Assessment Methodology

3.1 Chapter Summary

The assessment of flooding effects has involved the following steps using the AC and SG GIS to identify where:

- Desktop assessment to identify potential flooding locations, namely:

– Existing buildings appear to be near/within the existing flood plains.
– Where the Projects involve work near stream crossings and major overland flow paths.

- Flood modelling of the pre-development (without SGA) and post-development (with SGA) terrain, including:

– Flood modelling of the proposed future land use using Maximum Probable Development (MPD) development with the 100year ARI plus climate change rainfall
– Model results were used to identify changes in the flood water levels to create flood difference maps.

- Inspection of the flood difference maps to identify flooding effects, including:

– At key cross drainage locations such as culverts and where there are noticeable deep flood levels, consideration was given to flood hazard issues.
– Properties and buildings with habitable floors showing potential to flooding hazard through flood extent within the existing building footprints.

- A sensitivity analysis to assess the potential impact of extreme climate change (3.8°) compared to the existing projected climate change temperature increase (2.1°).

3.2 Outcomes based approach

The stormwater and flooding considerations are based on an indicative design and proposed designation boundary which incorporate flexibility for design changes to respond to the future environment and detailed design. The effects assessment is based on the Project being able to meet the requirements of the proposed designation condition and provide any required mitigation within the proposed designation boundary.

The proposed conditions for the future detailed design require the Project be designed to achieve the following outcomes:

- No increase in flood levels for existing authorised habitable floors that are already subject to flooding (that is, no increase in flood level where the flood level using the pre project model scenario is above the habitable floor level)
- No more than a 10% reduction in freeboard for existing authorised habitable floors (that is, if existing freeboard was 500mm, an acceptable change would be to reduce freeboard to 450mm)
- No increase of more than 50mm in flood level on land zoned for urban or future urban development where there is no existing habitable dwelling

- No new flood prone areas (with a flood prone area defined as a potential ponding area that relies on a single culvert for drainage and does not have an overland flow path)
- No more than a 10% average increase of flood hazard (defined as flow depth times velocity) for main access to authorised habitable dwellings existing at the time the Outline Plan is submitted.

Compliance with the recommended flooding outcomes, secured by the proposed condition, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

Where the above outcomes can be achieved through alternative measures outside of the designation such as flood stop banks, flood walls and overland flow paths, this may be agreed with the affected property owner and Auckland Council.

This assessment identifies where flood effects require consideration and the types of mitigation measures that could be implemented to address the effect. The designation boundary has been confirmed to provide sufficient land to accommodate those potential mitigation measures identified.

Compliance with these flooding outcomes would be demonstrated through a detailed stormwater design and further flood modelling of the pre-development and post-development 100year ARI flood levels (with allowances for MPD and climate change) at the resource consent stage.

3.3 Desktop Assessment

To identify locations considered to be at risk of flooding effects a desktop study was carried out to identify areas where:

- Existing buildings are near / within the existing flood plains
- The project involves carrying out significant work near the stream crossings / major overland flow paths
- The project may alter the existing flood plains, ponding volumes, and natural drainage paths.

The following reference materials were used to perform the desktop study:

- Whenuapai Structure Plan
- Auckland Unitary Plan Operative in Part
- Auckland Council GeoMaps
- Concept Design Drawings
- Flood maps created by the SGA modelling team
- Indicative Construction Methodologies
- NZTA Stormwater Specification P46
- New Zealand Bridge Manual (SP/M/022) for freeboard allowance.

A full list of references is provided in Section 13.

3.3.1 Recent flooding in Kumeū

Auckland Council 2022 Stormwater Conference paper (Kumeū Floods – Predicted twelve years earlier – Jahangir Islam et al.) noted the following:

> *"On the evening of August 30 last year, during a level 4 covid lockdown, an extreme weather event caused extensive flooding of community, residential and commercial areas across West Auckland. Winds gusts were predicted to a maximum of 90 km/h. Auckland Civil Defense &*

Emergency Management issued a weather watch alert from the NZ MetService of a potential incoming weather event for Auckland from 2pm and overnight on August 30, 2021. Emergency Services responded to requests for assistance during the event with emergency evacuations carried out overnight on the 30th and throughout the following day. Auckland Council (AC) received overall total of 210 emergency requests for service (RFS) jobs. Of the 210 RFS received by council, 6 homes were reported to have water entering living areas however many more were unreported.

Auckland Region's second largest river system recorded the largest flood on record over the 43-year monitoring period at the Waimauku flow gauging site on the Kaipara River. The river flood level peaked at 9:30am on August 31. The recorded flood level was half a meter above the 1979 highest previously recorded flood level. The Rain Radar rainfall indicated 24-hour totals from the radar were greater than 230mm in Taupaki Catchment, upstream of Kumeū township".

The Auckland Council paper identified the August 2021 event was greater than 250year return period and the modelling was based on existing impervious coverage which is less than the future, fully developed, impervious coverage.

The impact of the flooding in Kumeū was significant and included a large area of commercial development adjacent to State Highway 16 (SH16). The road itself was also affected and was closed for eight hours due to flood waters.

Figure 3-1 Flooding closed the main road in Kumeū. (Source: 1 NEWS)

Figure 3-2 A house surrounded by flood waters in Auckland's Kumeū. (Source: 1 NEWS)

It is acknowledged that there is an existing flooding issue in the Kumeū township area which this project will not solve. The flood effects assessment has focused on ensuring that additional flood effects are not created as a result of the Project and to mitigate any increased flooding created by the Project where possible.

As noted in section 3.4.2 the model is conservative and assumes maximum probable development (MPD) land use without any additional attenuation delivered through other developments. The increased roadway imperviousness attenuation allowed for in this Project also has not been allowed in the modelling.

It is anticipated that there will be a further response to flooding in the North-West from developers and Council and further consideration should be given at the detailed design stage for flooding in the Kumeū township area.

3.4 Flood Modelling

3.4.1 Stormwater Catchment Overview

The Northwest Strategic Package projects are situated within four stormwater catchments namely, Kumeū-Huapai, Taupaki, Redhills and Whenuapai as shown in Figure 3-3 below.

Kumeū-Huapai catchment is 3,865Ha and is drained northwards by the Kumeū River and Ahukuramu Stream. The Taupaki catchment is 3,977Ha and is drained by two major unknown streams that converge into the Pakinui Stream. The catchment receiving environment for the Kumeū-Huapai and Taupaki is known as Kaipara, as they discharge to the Kaipara Harbour

Redhills catchment is approximately 1,366Ha and drains via two major streams namely, Waiteputa Stream and Ngongetepara Stream. The catchment receiving environment is Waitemata catchment.

Whenuapai catchment size is 1,931Ha and is drained by numerous creeks and streams, including Brigham Creek that forms the area's north-western boundary and Waiarohia Inlet which forms the area's north-eastern boundary. The catchment has two primary stream catchments, namely Totara Creek flowing to Brigham Creek and Waiarohia Stream flowing to the Waiarohia Inlet.

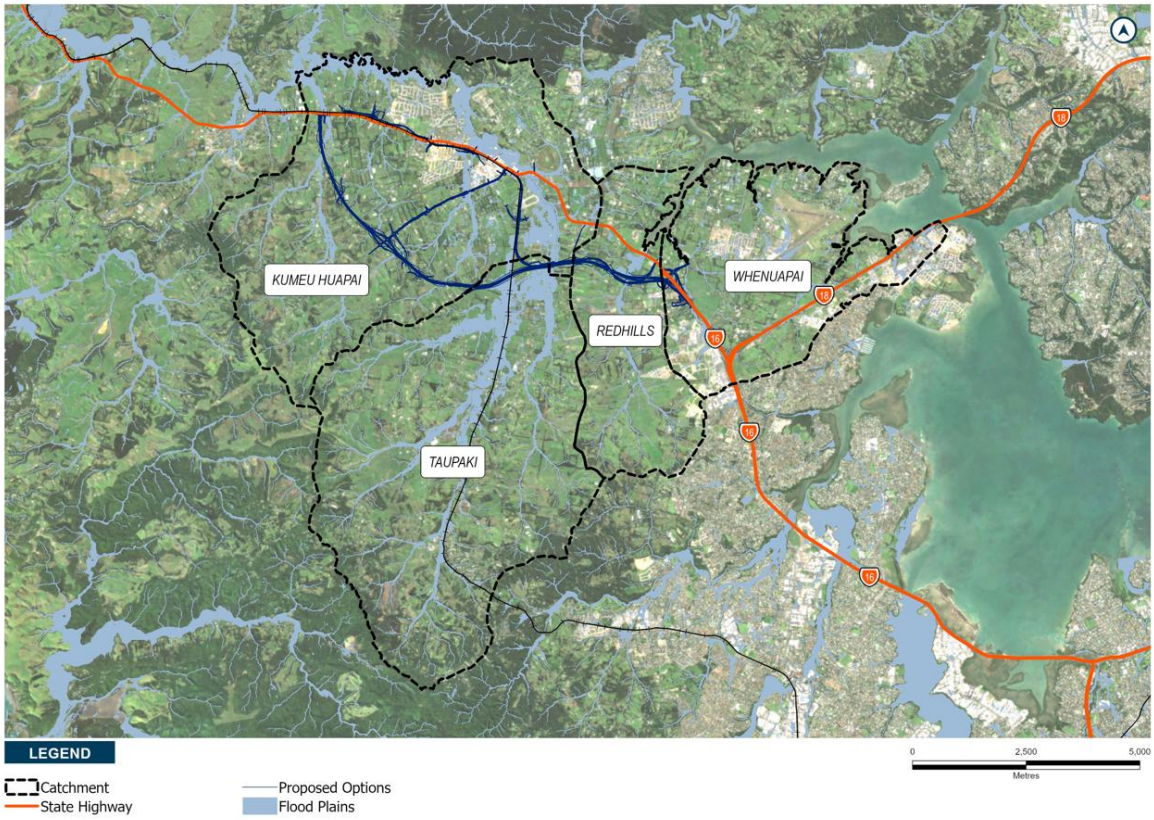

Figure 3-3: Existing 100yr ARI flood plain for Kumeū-Huapai Catchment (Auckland Council GIS)

3.4.2 Modelling Parameters

Auckland Council had produced Redhills and Whenuapai Rapid Flood Hazard Assessment catchment models which were adapted for this assessment. The Kumeū-Huapai-Taupaki model was developed by the SGA Modelling team using TUFLOW software.

To assess the flooding effects of the Projects on these catchments, two scenarios were considered for each NoR:

The two scenarios modelled for the assessment of effects were:

Scenario 1: Pre-development (without SGA)

- Future 100yr ARI rainfall events with 2.1° C of temperature increase to reflect climate change and future land-use without the project in place

Scenario 2: Post-development (with SGA)

- Future 100yr ARI rainfall events with 2.1° C temperature increase to reflect climate change and future land-use with the project in place
-

- For the sensitivity analysis a further two scenarios were modelled:

Scenario 3: Pre-development increased climate change (without SGA)

- Future 100yr ARI rainfall event with 3.8 ° C of temperature increase to reflect climate change and future land-use without the project in place

Scenario 4: post- development increased climate change (with SGA)

- Future 100yr ARI rainfall event with 3.8 ° C of temperature increase to reflect climate change and future land-use with the project in place

The proposed imperviousness for the maximum probable development (MPD) land use was applied, i.e. the model assumes the maximum impervious surface limits of the current zone or, if the land is zoned Future Urban in the Auckland Unitary Plan, the probable level of development arising from zone changes.

The modelling used an indicative design for the road which may not be the final design. The type and size of cross drainage structures are not fixed and will be verified for subsequent regional consenting and detailed design phases. Changes to these structures will alter the model outputs and upsizing the crossings may be required to mitigate upstream and downstream flood risk within design parameters.

New culverts have been added to convey flows at existing overland flow paths and some existing culverts have been extended to allow for the proposed road widening. To extend the culverts the existing grade has been extrapolated and the inlet and outlet invert levels have been established based on the existing pipe grade and overall length.

3.4.3 Climate Change

Climate change is accounted for in the model runs as per the revised Auckland Council (AC) Code of Practise (CoP) version 3 dated January 2022, which allows for 2.1°C of warming and a 16.8% increase on rainfall. A sensitivity analysis to understand the risk of increased climate change by comparing the results of 2.1°C of warming to 3.8°C of warming see Section 13.

For future detailed design climate change projections may be different to those used now along with rainfall inputs, impervious coverage and other modelling related parameters that can impact predicted model outputs and therefore mitigation needed to achieve flood neutrality.

3.4.4 Modelling Outputs

The modelling outputs were used to identify changes in predicted flood water levels and flooding extents. Increased flood hazard is associated with higher risk effects, for example a change in flood water level on land can result in the loss of use of the land or a reduction in the performance of drainage systems. The assessment criteria for the flooding assessment are shown in Table 3-1. For those areas identified as having potential flood effects mitigation measures have been proposed which can be confirmed at detailed design stage.

Table 3-1: Flooding effects assessment criteria

Effect	Change in flood water level on neighbouring property	Change in flood water level at habitable buildings
Positive	A reduction in flood level	A reduction in flood level
Negligible	Less than 0.05 m	Less than 0.05 m
Minor	0.05m to 0.5 m	0.05m to 0.15 m
Moderate	Greater than 0.5 m	Greater than 0.15 m

The required freeboard for bridges and culverts used to assess the suitability of the indicative design is set out in Table 3-2.

Table 3-2 Freeboard allowance for the level of serviceability to traffic (NZ Bridge Manual)

Waterway Structure	Situation	Freeboard	
		Measurement Points	Level (m)
Bridge	Normal circumstances	From the predicted peak flood water level to the underside of the superstructure	0.6
	Where the possibility that large trees may be carried down the waterway exists		1.2
Culvert	All situations	From the predicted flood water level to the road surface	0.5

3.4.5 Future Urban Zone

Development within the FUZ areas will change catchment hydrology, the terrain, building and property types that are potentially exposed to flooding. The assessment has therefore considered specific effects on existing properties and more generally considered effects on potential future development. It is anticipated that future developments will take account of flood risk and manage that risk within their development.

The model does not include the additional runoff generated by the increased impervious area from the new road as stormwater devices have been designed to adequately capture this additional runoff (see Section 3.6). However, the model does account for the increased impervious area as a result of development according to the AUP:OP zonings and the allowable impervious coverage within each zone.

Hence, the model output incorporates a degree of conservatism around future flood effects as it is anticipated that future developments outside the designation will need to design, construct and operate their own stormwater devices to ensure they can mitigate the stormwater generated by additional impervious areas to the pre-development scenario.

It is expected that coordination and integration of the corridor design with future development will be required to confirm and address potential future effects. Mitigation measures in the future detailed design will reflect the actual development in these areas. See Section 3.4.6 for more detail of the limitations of this assessment.

3.4.6 Model Limitations

All of the corridors have upstream and/or downstream catchments. The modelled scenarios use imperviousness assumptions associated with the future land use(s) shown in the Auckland Plan, Whenuapai Structure Plan and relevant Precinct Plans. However, it is probable that significant change in the catchments will take place before or shortly after the corridor is constructed.

The models include the existing roads and existing culverts where the culverts are 600 mm or greater. This modelling approach follows the Auckland Council Rapid Flood Hazard Assessment approach but allows for pipes down to 600mm to be modelled as opposed to 1200mm in the standard AC approach. This assumes that culverts < 600 mm diameter are considered to be fully blocked (which also aligns with the AC Code of Practise) although larger culverts are considered to be fully functional and no allowances for capacity reduction has been used.

Culverts have been added at selected crossings of the project corridors. However, the results from the models are considered appropriate to assess the relative or overall flooding effects due to the project corridors for the current stage of design.

The SGA design model is based on a preliminary design. The new culverts and bridges are indicative, they may not be the final solution as this will be determined by the detailed design. Future modelling will be used to ensure flood effects will be adequately mitigated and flood neutrality can be achieved.

The culvert sizes are an initial estimate used to assess the relative effects of flooding outside the corridors. Larger culverts can be constructed if required to mitigate effects with the size or levels of service. New or upgraded culverts will be confirmed at the future detailed design stage and will consider matters such as consent requirements, asset owner requirements, level of service, stream simulation design, fish passage, blockage.

3.5 Sensitivity Analysis

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given exposure[3]. In this instance the sensitivity of the designation to increased rainfall as a result of climate change has been considered.

As set out in Section 3.4.3, the flood model has allowed for 2.1°C of warming and a 16.8% increase on rainfall based on the AC CoP. However, given the uncertainty of climate change effects in the future the assessment has also considered a more severe climate change scenario based on 3.8°C of warming and a 32.7% increase in rainfall.

The results for 3.8°C of warming have been compared to those reported in the flood assessment for 2.1°C of warming and areas where higher rainfall may increase flooding have been identified. Further mitigation at these locations has been included where necessary to encourage flood resilience.

[3] Intergovernmental Panel on Climate Change. (2007). Climate Change 2007: Contribution of Working Group II to the Fourth Assessment Report. Cambridge, UK: Cambridge University Press.

In the future it is possible there may be different requirements for climate change. However, at this stage a pragmatic approach has been taken using the current design thinking (2.1°) along with a sensitivity analysis using the more extreme rainfall predictions (3.8°).

3.6 Stormwater management devices

While stormwater effects apart from flooding are not assessed, provision is made for the future management of potential stormwater effects (stormwater quantity and stormwater quality) by identifying the space required for stormwater management devices (SWMDs, i.e. treatment swale and wetlands) and incorporating land for that purpose into the NORs. In identifying the land required for these devices, preliminary sizing and siting has been undertaken and extra space allowed for constructing the works.

Some key assumptions that were used to identify the amount of land sought for stormwater management works within the designation include the following:

- Wetlands are sized to attenuate 100 year peak flows from the corridor (as of the required stormwater wetland sizing criteria this gives the largest footprint). Quality and retention/detention requirements are able to fit within the footprint
- Allowance is made for wetland attenuation storage and hydraulic gradients from corridor inlet to discharge point (typically a minimum of 2.0 to 2.5m vertically)
- Wetland geometry and footprints were modelled to determine the required cut and fill and a 15m buffer added for construction purposes and maintenance access
- A minimum 6m buffer is provided around the corridor earthworks extents to provide space for construction purposes and allow for works such as drainage channels and culvert inlets/outlets and flexibility in the vertical alignment
- Diversion channels are identified where they are needed to prevent upstream flooding.

These allowances are considered appropriate for sizing the devices at this early stage of the design process and also provide some flexibility for future refinement. The design of devices is not discussed further in this report as this is considered a matter that will be developed further for the future regional consents and implementation processes.

In general, the approach has been to avoid SWMDs in floodplains where possible. If this is not possible, the design has sought to employ offline systems located in low velocity flood zones where has minimal risk of scour for resilient and maintainable systems.

The flood model does not account for the flood water storage capacity provided by the proposed SWMDs (wetlands or swales) even though they are designed with attenuation capacity for the additional runoff generated by the increased impervious area from the new road infrastructure.

While the project is not intended to remediate existing flood hazards, it is anticipated the proposed SWMDs will provide improvements in water quality and attenuation where practicable.

4 Strategic Assessment Package Overview

An overview of the Strategic Assessment Package is provided in Figure 4-1 below, with a brief summary of the Strategic Assessment Package projects provided in Table 4-1.

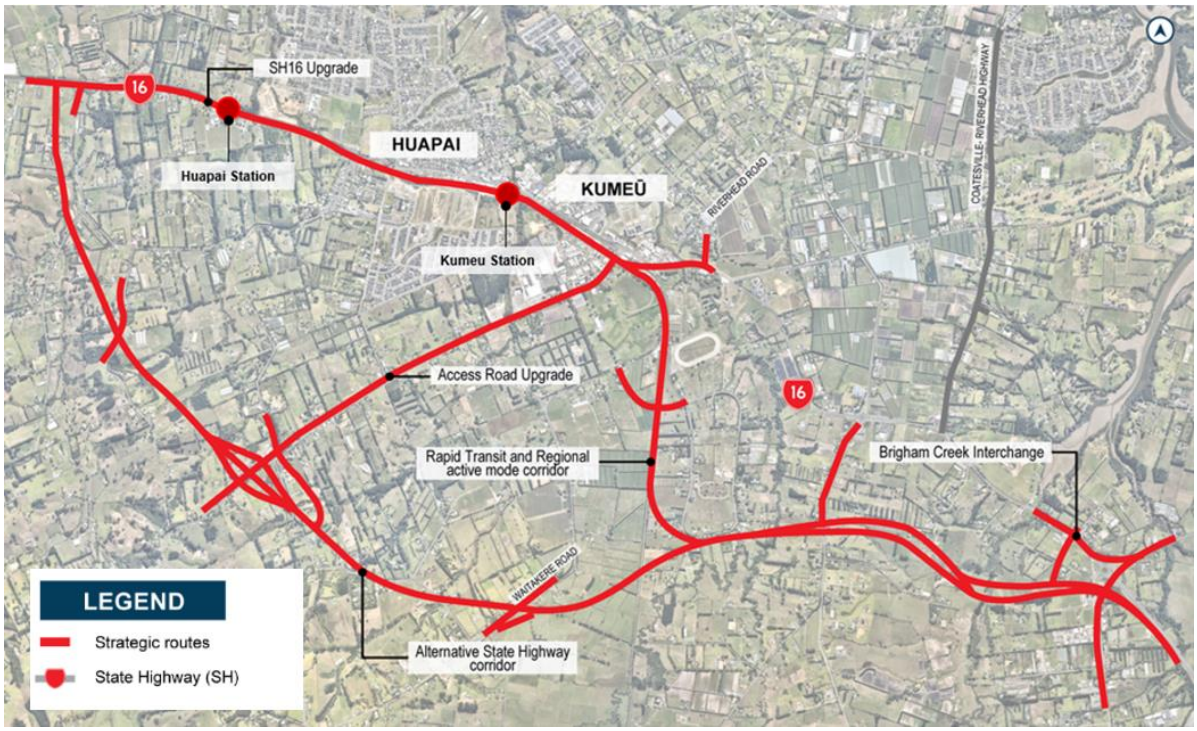

Figure 4-1: Northwest Strategic Assessment Package – Overview of NoRs for Assessment

Table 4-1: Strategic Assessment Package Project Summary

Corridor	NOR	Description	Requiring Authority
Alternative State Highway	S1	A new four-laned dual carriageway motorway and the upgrade of Brigham Creek Interchange.	Waka Kotahi
State Highway 16 Main Road Upgrade (alteration to existing designation 6766)	S2	Upgrade to urban corridor including active modes and realignment of Station Road intersection with SH16.	Waka Kotahi
Rapid Transit Corridor	S3	New Rapid Transit Corridor and active mode corridor in one co-located corridor.	Waka Kotahi
Kumeū RTC Station	KS	New rapid transit station, including transport interchange facilities and accessway.	Waka Kotahi
Huapai RTC Station	HS	New rapid transit station, including transport interchange facilities, park and ride and accessway.	Waka Kotahi
Access Road Upgrade		Upgrade of Access Road to a four-lane cross-section with separated cycle lanes and footpaths on both sides of the corridor.	Auckland Transport

Please refer to the AEE for further information on these projects, including a project description, key project features and the planning context.

5 Summary of Modelling Results

A summary of the operational effects for each of the corridors is set out in Table 5-1 below and discussed in more detail in Section 8.

Indicative mitigation measures have been provided in in Section 8 which will minimise flooding effects and help enable the outcomes set out in Section 3.2 to be met. The outcomes generally reflect a negligible up to minor flood effect i.e. <0.05m increase in flood depth. The outcomes set out in Section 3.2 will form part of the designation conditions and compliance with those conditions will ensure the residual flood effects for all NoRs will be negligible up to minor.

Table 5-1: Summary of flood modelling results

Corridor name	Location	Potential effect without mitigation	Potential effect with implementation of the recommended flooding outcomes
NoR S1	Ngongetepara Stream crossing (Points 15A and 4A in Figure 9-1)	+0.17m upstream, +0.03m downstream Minor effect upstream, no effect downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Pomona Road (Point 57 and Point 58 in Figure 9-2)	-0.50m upstream, +0.03m downstream Positive effect upstream and negligible effect downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Totara Creek (Points 14A and 2A in Figure 9-3)	+0.09m upstream, +0.52m downstream Minor effect upstream, moderate effect downstream Less than 1.2m freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Karure Stream (Point 5A and 16A in Figure 9-4)	+0.58m upstream, +1.63m downstream Moderate effect upstream and downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Boord Crescent (Point 6A and 7A in Figure 9-6)	+1.52m upstream, +0.32m downstream Moderate effect upstream and minor effect downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Pomona Road crossings	+0.25m upstream, +0.06m downstream	No more than 0.05 m increase in flood level, Negligible up to minor effect

Corridor name	Location	Potential effect without mitigation	Potential effect with implementation of the recommended flooding outcomes
	(Points 10A and 11A in Figure 9-2)	Moderate effect upstream and minor effect downstream Adequate freeboard	
	Foster Road crossings (Point 71 and Point 72 in Figure 9-8)	+0.49m upstream, -0.01m downstream Moderate effect upstream, positive effect downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
NoR S2	Kumeū Township (Point SH7)	+0.30 m Moderate effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Foster Road (Point 12A and 13A in Figure 10-3)	+0.09m upstream, +0.09m downstream Minor effect upstream and downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Main Road (Point 29 and 30 in Figure 10-4)	+0.79m upstream, -0.27m downstream Moderate effect upstream and positive effect downstream	No more than 0.05 m increase in flood level, Negligible up to minor effect
NoR S3, NoR KS, NoR HS	RTC / RAMC (Point 31 and 32 in Figure 10-4)	+0.67m upstream, -0.27m downstream Moderate effect upstream and minor effect downstream	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Karure Stream crossing (Point RTC2 in Figure 9-4)	+1.74 m Moderate effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Kumeū Rapid Transit Station (RAMC1 in Figure 11-1)	0.0 m	no flood hazard effects
	Huapai Rapid Transit Station (Point 27 and 28 in Figure 10-4)	+0.25m upstream, +0.05m downstream Minor effect upstream, negligible effect downstream	No more than 0.05 m increase in flood level, Negligible up to minor effect
NoR S4	Unnamed stream crossing (Point 1C and 2C in Figure 12-1)	+0.01m upstream, -0.04m downstream Negligible effect upstream, positive effect downstream Adequate freeboard	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Access Road (Point AC1 to AC3 in Figure 12-1)	+0.12 m to +0.22 m Minor to moderate effect	No more than 0.05 m increase in flood level, Negligible up to minor effect

6 Strategic Positive Effects

The positive effects for projects are those where the predicted 100yr ARI flood level difference map shows a decrease in water levels and an increase in freeboard for bridges, culverts and habitable buildings using the criteria set out in

Table 3-1 and Table 3-2. There are positive flooding effects for all NoRs.

Positive flooding effects for the projects include raising the existing road levels which will have a positive effect for road users by preventing flood flows across the road and reducing flood hazard.

Where new bridges are proposed, the maximum freeboard requirement has been adopted to provide flood resilience. The positive effects from the proposed new bridges identified by the model include:

- All proposed new bridges have a freeboard of 1.2 m, including over Totara Creek, Ngongetepara Stream and Kumeū River.
- New bridges over Totara Creek, Ngongetepara Stream and Kumeū River which have been confirmed to increase the freeboard for the road and decrease water levels upstream and downstream of the bridge crossing for the 100yr ARI flood level.

The projects create the opportunity to improve existing culvert capacities and/or propose new culvert crossings to improve overland and stream flow in the area. For example, at Chainage 4140 there is a positive effect upstream due to increased conveyance under the road.

It is noted that the proposed culverts and bridges form part of the indicative design and the final design may include different crossings. The final design will be subject to further flood modelling at the detailed design stage. The final design will ensure that adequately mitigated and flood neutrality can be achieved.

7 Strategic Construction Effects

The construction effects apply to the entire project, however based on the location of works in terms overland flows or known flood extents in the vicinity. The proposed construction works which can result in flooding effects include:

- Construction of new culvert crossings or upgrading of existing culvert crossings
- Construction of new bridges over streams or overland flow paths
- Installation of diversion drains / realignment of existing overland flow paths
- Construction of new wetlands
- Temporary use of lay down areas.

For all NoRs there is an increased flood risk for the proposed construction works. The potential effects of these are:

- Bulk earthworks to complete the contouring for new landscape features e.g. wetlands and new or upgraded culverts require a dry works area and can alter overland flow paths or generate erosion and sediment effects
- The construction of new bridges over streams will require temporary staging platforms for piling rigs and cranes to be constructed on the banks and possibly over the stream bed and potentially causing a constriction to flood flows and raising upstream flood levels
- The siting of wetlands within an existing overland flow path can obstruct runoff and result in flows being diverted towards existing properties.

Section 7.1 below describes methods for minimising/mitigating these potential effects.

7.1 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

The management and mitigation measures for construction effects are:

General:

- Carrying out earthworks during the summer / dry months to reduce the risk of flooding
- Locating lay down areas outside of existing overland flow paths
- Managing the overland flow paths to make sure flows are not diverted toward existing buildings or properties
- Construction Environmental Management Plan (CEMP) be developed prior to construction by an experienced Stormwater Engineer and shall consider the effects of temporary works, earthworks, storage of materials and temporary diversion and drainage on flow paths, flow level and velocity. Including:
  - Siting construction yards and stockpiles outside the flood plain
  - Diverting overland flow paths away from area of work
  - Minimizing the physical obstruction to flood flows at the road sag points
  - Staging and programming to provide new drainage prior to raising road design levels and carry out work when there is less risk of high flow events

- Methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events).

Construction of new and existing culvert crossings and wetlands:

- Existing culvert extensions should be done prior to commencement of bulk earthworks to allow for the passage of clean water across the site
- Installing temporary diversions or to allow flows to be maintained while new culverts and wetlands are constructed
- For larger embankments requiring a longer duration of works or for overland flow paths with more regular and higher flow rates diversions should be installed prior to works commencing
- Where no diversion is required a 6m working clearance between any earthworks and designation boundary should be adopted to accommodate access and materials
- For larger diameter pipes a working clearance of ±20m from the upstream extent and ±15m from the downstream extents should be provided.

Construction of new bridges:

- Temporary platforms should generally be set back as far as practicable from the stream banks and main channel to minimise the risk of flooding

Staging of earthworks for the abutments and stockpiling of materials outside the flood plain to mitigate the potential for blocking flow paths and flood plains.

8 Strategic Operational Effects

There are a range of operational effects particularly from proposed new bridges and crossings. The model is based on an indicative design which may be subject to further refinement and it may be that some of these structures are modified in the future. For the project the assessment of operational flooding effects considered:

- New culvert crossings (≥ 600 mm diameter)
- New bridge structures at Totara Creek, Ngongetepara Stream, Kumeū River and its tributaries, and Ahukuramu Stream
- Significant areas where the new road embankment encroaches existing flood prone areas
- The extent of flooding on existing properties due to the new project corridor

The effects of these are:

- Increasing impervious areas resulting in increased runoff and potentially increased flood levels
- Altering existing overland flow paths resulting in flows being redirected towards existing properties
- Obstructing an existing overland flow path resulting in ponding at existing low points or newly created depressions along the corridor
- Improving flows under the road reducing upstream flood levels and increasing flood levels at properties further downstream.

The new bridge structures resulted in positive effects (see Section 6). For the culverts the effects were considered to be negligible to moderate prior to mitigation. This includes all NoRs (see Table 5-1).

The mitigation measures set out in Section 8.1 have been designed to assist in minimising flood effects. There are a range of potential mitigation measures that can be applied and additional modelling during detailed design will consider which measures are most appropriate to ensure adverse flood effects are minimised, remedied or mitigated. The detailed design would then need to demonstrate compliance with outcomes set out in Section 3.2 as required by an appropriate designation condition.

8.1 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

It is recommended that during detailed design additional flood modelling is carried out and mitigation measures implemented as required to achieve the outcomes set out in Section 3.2. Compliance with these outcomes will be required as a designation condition. Based on the interim design potential mitigation measures have been identified in order to show that the feasibility to meet these outcomes has been considered.

Mitigation measures which may be implemented include:

- Creating new overland flow path diversions to discharge to nearby overland flow paths or streams to mitigate ponding and decrease flood levels at affected properties
- Increasing culvert sizes so that the upstream and downstream water level differences do not increase by more than 0.5m on land zoned for urban and future urban development
- Upgrading culverts by adding smaller culverts to create a balance between the flood level differences upstream and downstream

- Installing drains at the toe of embankment sloping towards the culverts can also allow for additional storage to decrease the velocity and peak flow through the culvert crossings
- Optimising the proposed bridge span and freeboard during detailed design
- Integrating development design requirements for FUZ upstream and downstream of the proposed corridor.

Where the above outcomes can be achieved through alternative measures outside of the designation such as flood stop banks, flood walls and overland flow paths, this may be agreed with the affected property owner and Auckland Council.

9 NoR S1: Alternative State Highway, including Brigham Creek Interchange

9.1 Project Corridor Features

9.1.1 Catchment Characteristics

The corridor crosses several overland flow paths and six major streams, namely Totara Creek, Ngongetepara Stream, Karure Stream, Kumeū River and Ahukuramu Stream. The existing 100year ARI flood maps from the latest catchment models with MPD and existing terrain show flooding at:

- new potential bridge crossings at Totara Creek, Ngongetepara Stream, Kumeū River, unnamed streams at Chainages 7,200 and 10,000
- properties at 32, 40 and 44 Brookvale Lane, Taupaki; and
- properties at 116 Foster Road, Huapai.

Existing flood prone areas from Auckland Council Geomaps are evident where overland flow paths and streams traverse the corridor.

9.2 Existing and Likely Future Environment

9.2.1 Planning Context

The Alternative State Highway (**ASH**) corridor, including the Brigham Creek Interchange (**BCI**), is largely rural and is proposed to traverse land zoned under the AUP:OP as Rural – Countryside Living Zone, Rural – Mixed Rural Zone and Rural – Rural Production Zones.

The ASH corridor will also traverse two separate areas of FUZ in Redhills North and Kumeū-Huapai with the Brigham Creek Interchange also currently sitting within proposed FUZ land. Table 9-1 below provides a summary of the existing and likely future environment as it relates to the ASH and BCI.

Table 9-1: Alternative State Highway and Brigham Creek Interchange Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[4]	Likely Future Environment[5]
Rural	Rural - Mixed Rural Zone, Rural - Countryside Living Zone Rural - Production Zone	Low	Rural
Undeveloped greenfield areas	Future Urban	High	Urban

[4] Based on AUP:OP zoning/policy direction
[5] Based on AUP:OP zoning/policy direction

Please refer to the AEE for further information on the planning context.

9.3 Proposed works

For NoR S1 the Project involves the construction of a new four-lane motorway corridor with a cross-section of approximately 50m to accommodate a four-lane dual carriageway and separated cycle lanes and footpaths. The typical cross section includes an active mode corridor with central and side barriers.

An underpass is proposed at Taupaki Road and bridges over the NAL with further grade separations at Waitakere Road, Pomona Road, Tawa Road, Puke Road and Foster Road.

Other proposed works in NoR S1 which are relevant for the flooding assessment include:

- Construction of new bridges over Totara Creek, Ahukuramu Stream, Ngongetepara Stream, Kumeū River and tributaries
- Construction of new culvert crossings for overland flow paths / streams
- Construction of diversion drains / realignment of overland flow paths
- Construction of new wetlands of which two (ASH Wetland 5 and 15) are partially within the current 100year flood plain [6].

9.4 Assessment of Flooding Effects and Measures to Avoid, Remedy or Mitigate Actual or Potential Adverse Effects

9.4.1 Positive Effects

Ngongetepara Stream bridge crossing

New bridges are also proposed at Ngongetepara Stream (Points 15A and 4A in Figure 9-1) which will increase the freeboard for the road with the bridge soffit > 1.2m. This reduces the potential flood effects for road users.

[6] The preference is to locate wetlands outside of the flood plain where possible. There is flexibility within the designation to design stormwater ponds to avoid the floodplain and this will be confirmed at outline plan stage through the final design

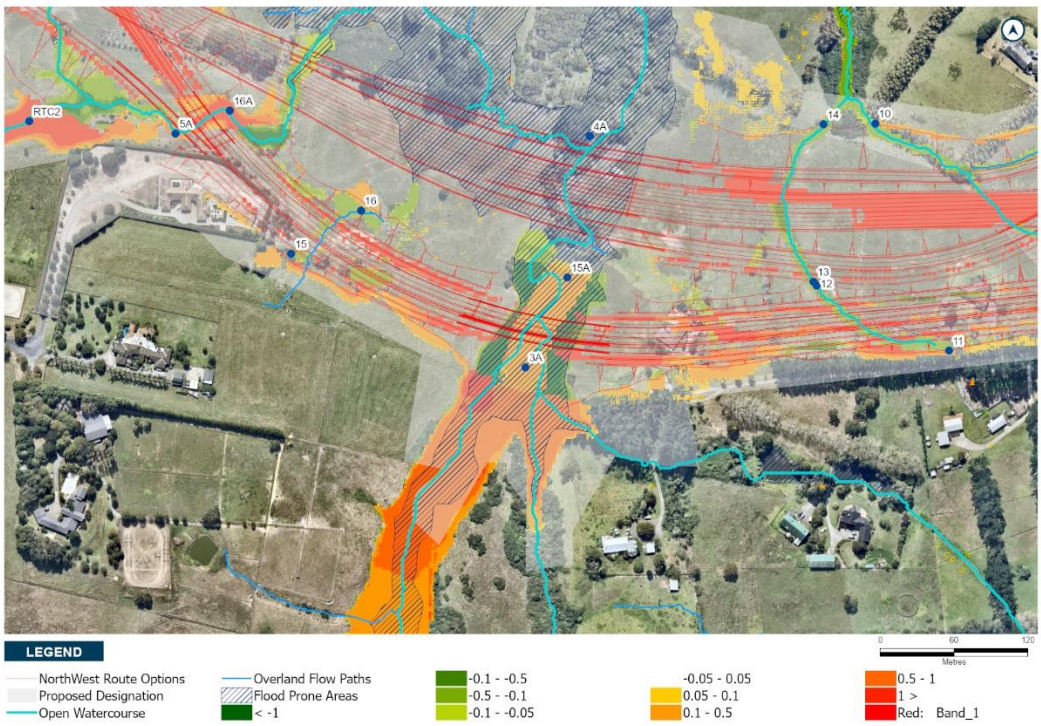

Figure 9-1: Flood Difference Maps for Ngongetepara Stream bridge crossing

The new proposed culvert crossing at 73 Pomona Road (Chainage 7900) shows a decrease in the 100year ARI flood level upstream and a decrease downstream of the crossing (Point 57 and Point 58 in Figure 9-2). The level between the design road level centre line and the flood level is 12.7m freeboard which is above the 0.5m freeboard required over a culvert. Similarly, the new crossing proposed at 146 Motu Road (Chainage 7400) shows a decrease of -0.02m upstream and -0.19m downstream which is a positive effect.

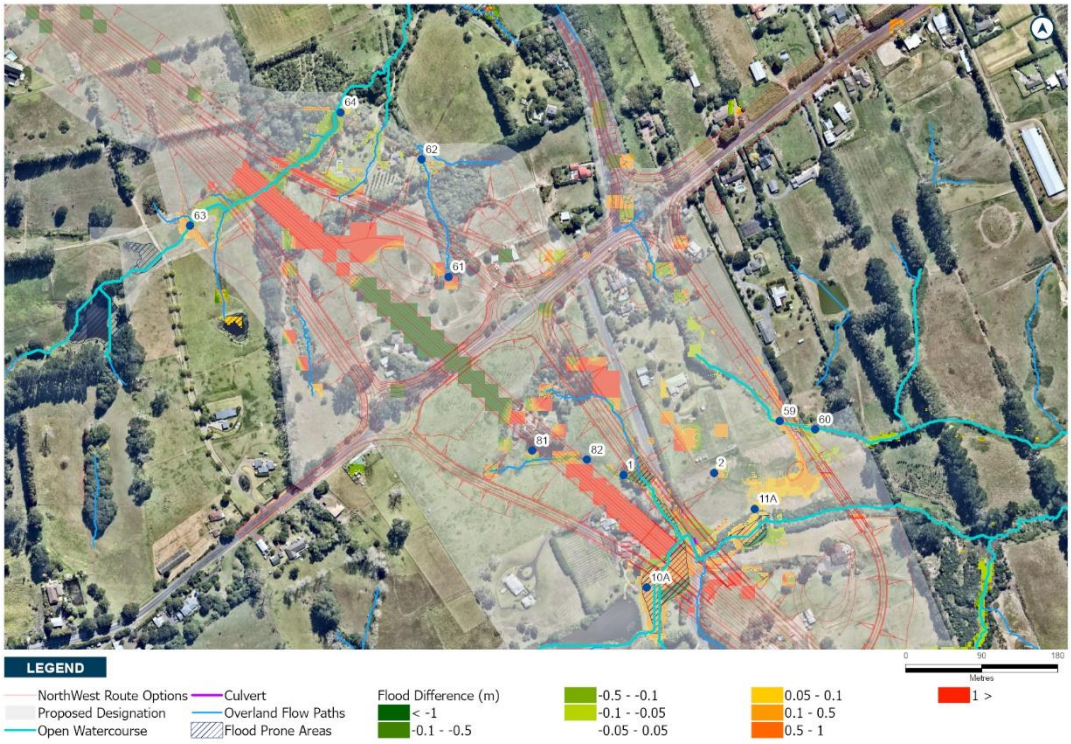

Figure 9-2: Flood Difference Maps for Pomona Road

9.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 7 above.

Stream crossings are key sites for potential flooding effects during construction, this includes:

- Totara Creek
- Ngongetepara Stream
- Unnamed Stream
- Unnamed Stream and Pomona Road
- Kumeū River
- Ahukuramu Stream

9.4.3 Recommended measures to avoid, remedy or mitigate construction effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes. Various culverts need to be installed or upgraded. There could be increased flood levels or new flow paths created during construction if adequate flow diversions are not provided.

The potential flooding effects during construction will be considered by, and managed through, flood risk mitigation measures to be set out in the Construction Environmental Management Plan (CEMP).

Lay down areas will be confirmed during the construction phase and therefore siting them with respect to flooding constraints should be considered further through the CEMP.

All other mitigation measures as set out in Section 7.1 apply.

9.4.4 Assessment of Operational Effects

9.4.4.1 Brigham Creek Interchange

Totara Creek bridge crossing

The proposed 30m Totara Creek bridge spans across a 30m wide 100year ARI flood plain with bridge piers set outside the main river channel.

The results for the 100year ARI pre-development scenario show that the flood level at the location of the proposed bridge structure is RL 17.59m upstream and RL 14.34m downstream. For post-development the flood level increases to RL 17.68 (+0.06 m) upstream and RL 14.86m (+0.63 m) downstream (refer to Points 14A and 2A in Figure 9-3). The potential effects of the bridge on flood hazards are considered minor upstream and moderate downstream.

The structure has a freeboard of 0.72m between the 100year ARI flood level and bridge soffit which is below the 1.2m required freeboard. However, there are no effects on any nearby buildings. Potential mitigation options include lifting the alignment to increase freeboard. The designation boundary includes sufficient area to enable mitigation to be undertaken and a final solution can be at a future stage of design.

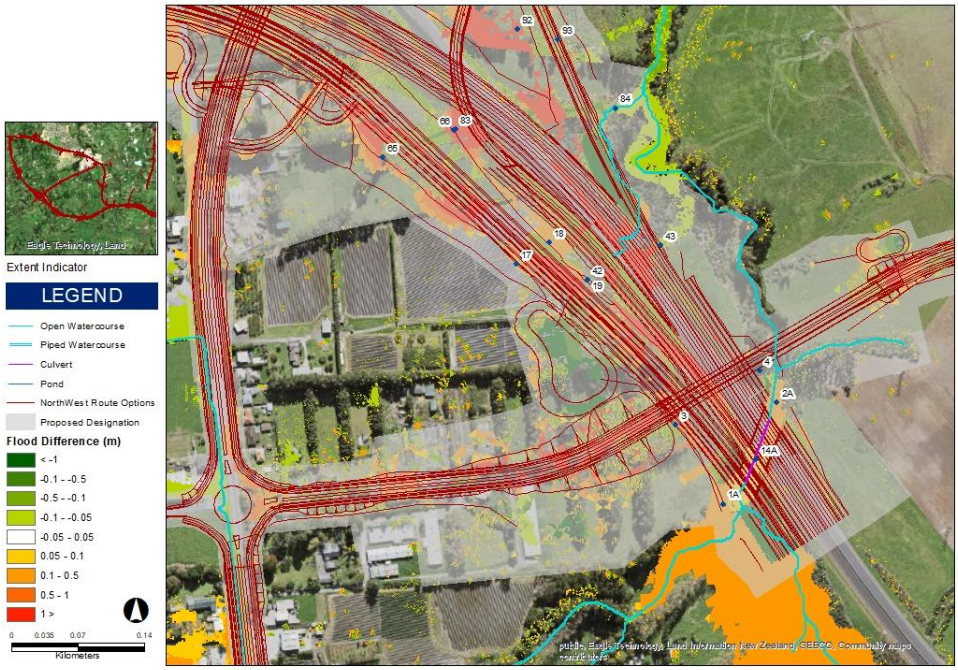

Figure 9-3: Flood Difference Maps for Totara Creek bridge crossing

Karure Stream crossing

The Karure Stream bridge provides adequate freeboard (+2.86 m) however, there is a moderate effect upstream and downstream of this crossing (+0.58m upstream, +1.63m downstream). Mitigation

at this location is to increase the bridge opening to ensure that stream is not obstructed by embankments to avoid flood effects. This is possible within the existing designation boundary and a final solution can be addressed at a future stage of design.

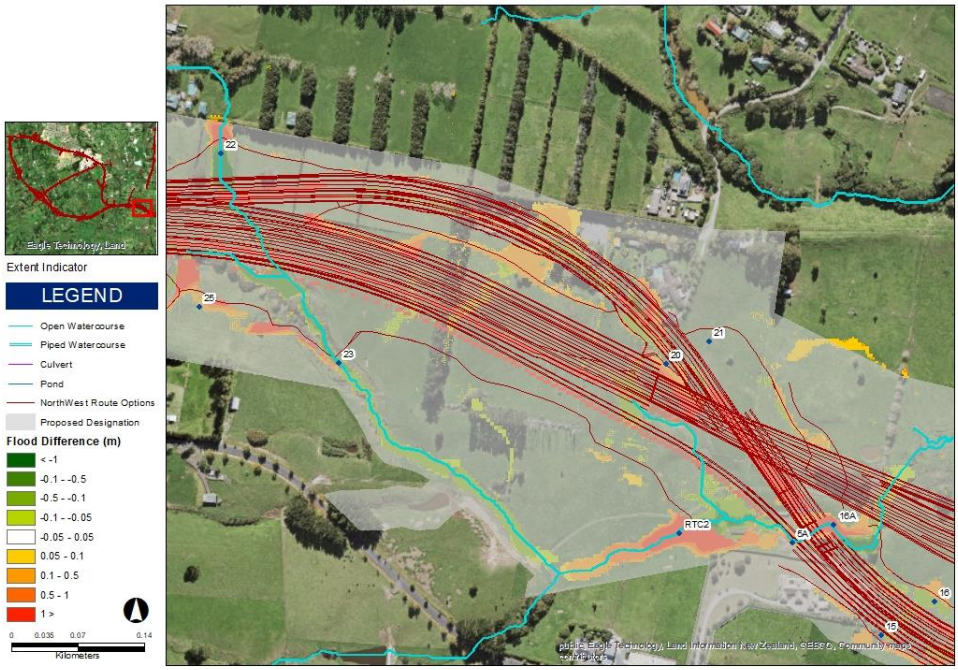

Figure 9-4: Flood Difference Maps for Karure Stream crossing

9.4.4.2 Boord Crescent, Kumeu

At this location there is a permanent stream which runs parallel to the proposed alignment. Consideration should be given to adjusting the alignment to avoid the stream or to provide a bridge crossing. A bridge crossing would also help to avoid a moderate effect for flood hazard at 182 Boord Crescent (Chainage 3300, Point 6A and 7A in Figure 9-6). Both the unnamed stream crossing and the crossing adjacent to the railway line are too narrow and could be widened to allow for more water to pass under the road alignment. Additional crossings will be required under the RTC and railway line to allow water to move from east to west to help balance the additional capacity provided a wider bridge opening(s). This mitigation could be accommodated within the designation the final solution will be provided at a future stage of design.

Wetland 5 at 176A Boord Crescent is located partially within the flood plain due to its size. However, during design and construction the flood plain will be modified by the proposed bridge. As a result of the changed terrain the flood plain would be diverted away from the wetland. Therefore, this is considered to have a negligible effect on flood hazard.

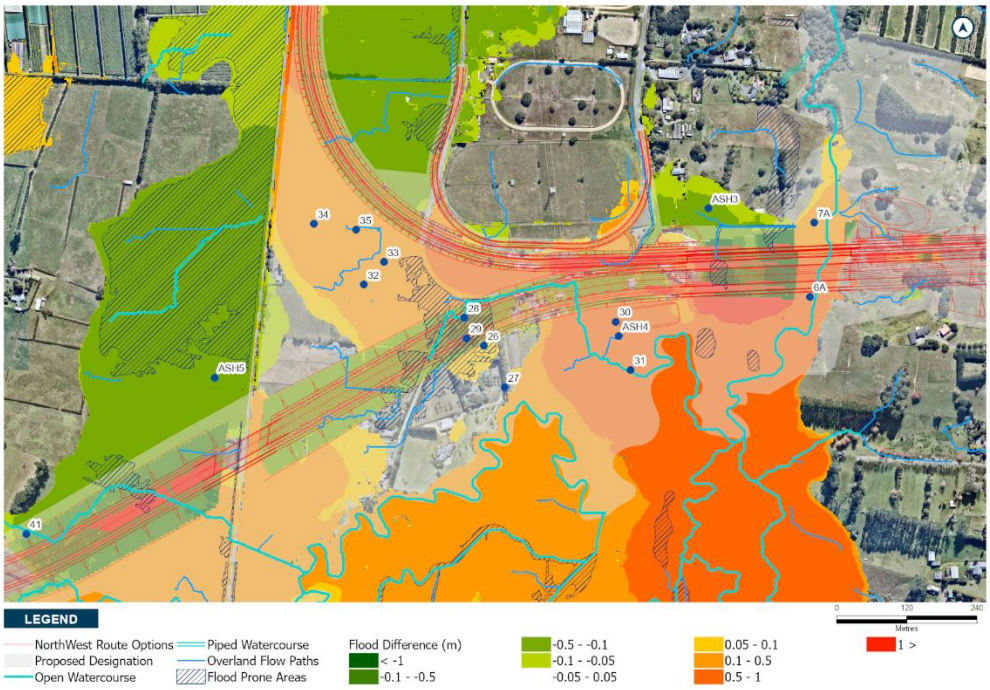

Figure 9-5: Flood Difference Maps for Boord Crescent

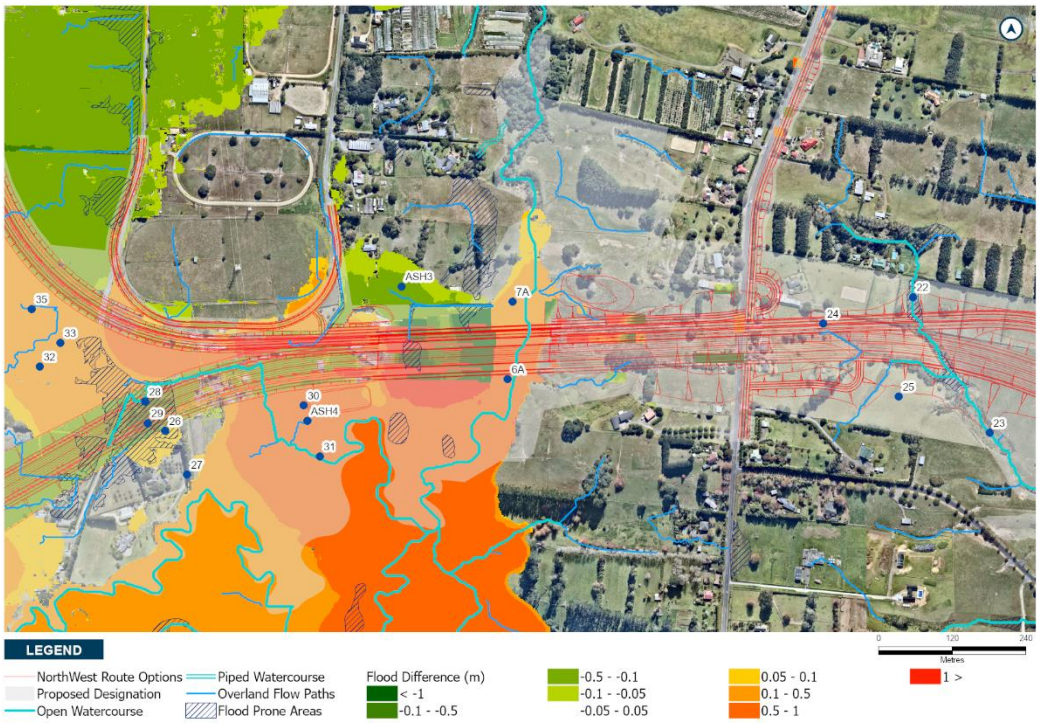

Figure 9-6: Flood Difference Maps for Boord Crescent

9.4.4.3 Pomona Road

For the crossing at 191 Pomona Road (Chainage 5820-5980, Points 8A and 9A in Figure 9-7) there is a minor effect directly upstream and a positive effect downstream. However, there is additional areas

with an increase flood hazard upstream of the crossing (Points ASH1 and ASH8) which sees an increase in flood level more than 0.5m on areas of open space which is a moderate effect. The effect is due to a lack of drainage being modelled. Mitigation could include realigning the existing overland flow path alongside the embankment toe to discharge under the crossing. This can be provided within the designation the final mitigation will be confirmed during detailed design.

The proposed new crossing at 34 Pomona Road (Chainage 7200, Points 10A and 11A in Figure 9-2) shows an increase in flood hazard of +0.30m upstream and +0.07m downstream which is a minor effect. Mitigation could include design of the bridge to achieve flood neutrality. This can be done within the designation boundary and a final solution can be addressed at a future stage of design.

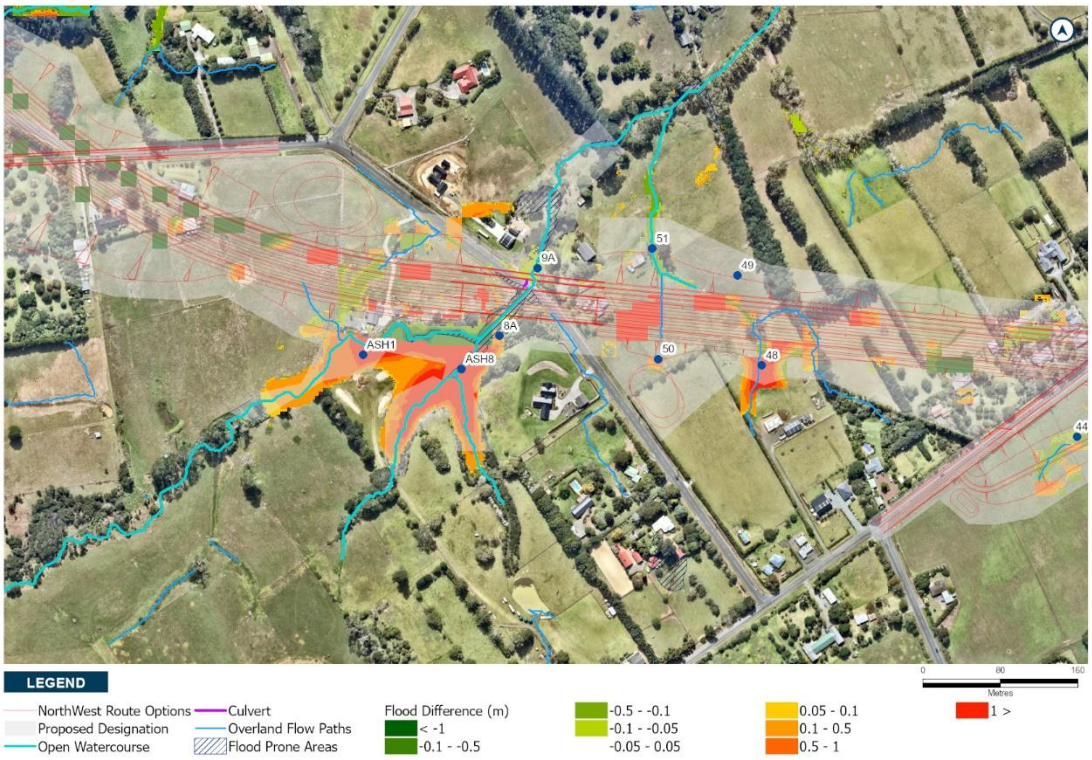

Figure 9-7: Flood Difference Maps for Pomona Road

9.4.4.4 Foster Road

At 62 Foster Road (Chainage 9500, Point FR1 and FR2 in Figure 9-8) the embankment is obstructing an overland flow path. Mitigation should ensure the size and the orientation of the embankments are optimised to avoid this effect. This can be done within the existing designation and the final mitigation will be confirmed at detailed design.

The new proposed culvert crossing at 58 Foster Road (Chainage 9700) shows an increase in the 100year ARI flood level upstream of the crossing. The level between the design road level centre line and the flood level is ± 3.33m freeboard which is above the 0.5m freeboard required over a culvert. The flood difference map shows an increase greater than 0.5m upstream which is considered a moderate effect (Point 71 and Point 72 in Figure 9-8).

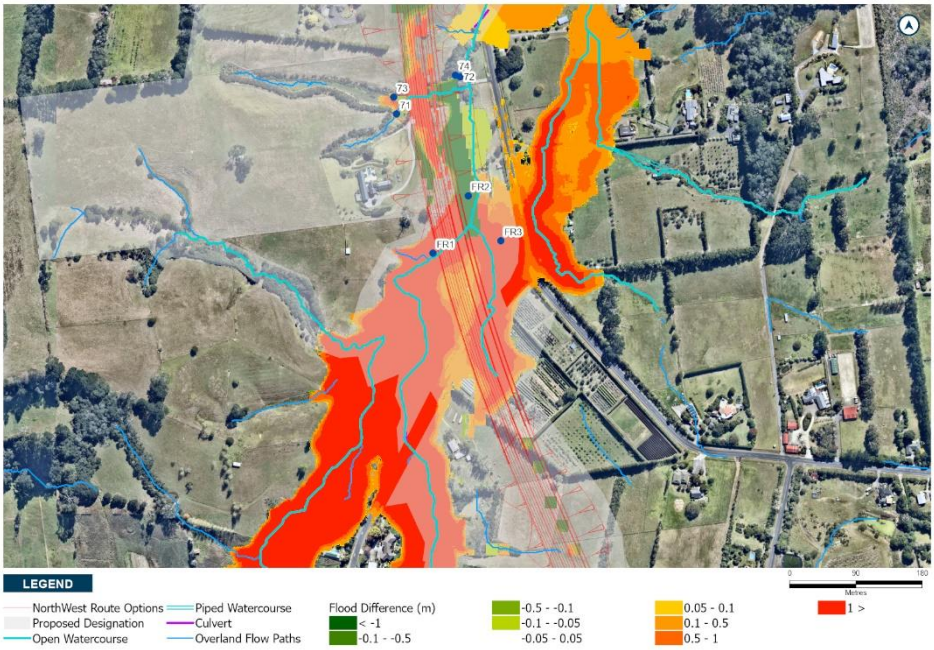

Figure 9-8: Flood Difference Maps for Foster Road

Wetland 14 at 23 Foster Road is partially within the flood plain, however only a berm is located within flood plain. This could be confirmed at detailed design with the potential for the pond design to be adjusted.

Wetland 15, at the intersection of Foster Road and SH16, is located within the current flood plain, however the proposed location is between two new alignment and both are raised so will change the flood plain behaviour. It is likely in the future in this location the terrain will change. The bridge located on SH16 (NoR S3) and the intersection of Foster Road may need to consider providing a wider overland flow path to mimic the existing flood plain, this is discussed in Section 10.5.1.3.

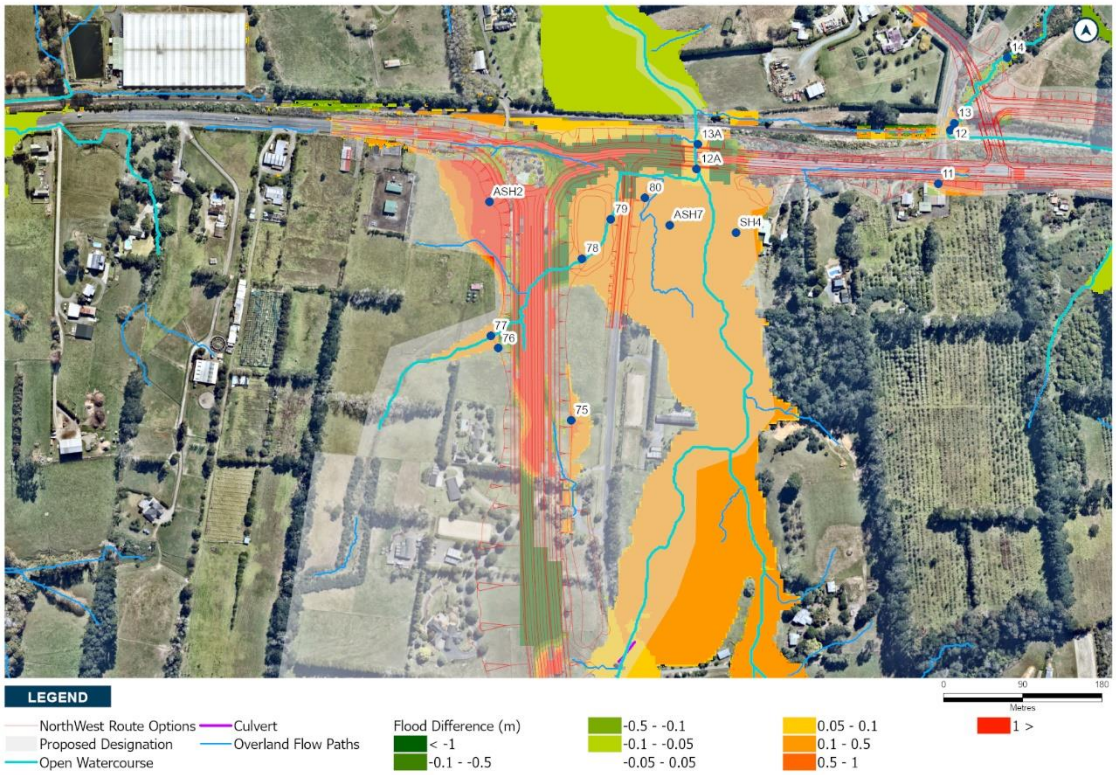

Figure 9-9: Flood Difference Maps for Foster Road

9.4.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The potential mitigation measures could be adopted as set out in Section 8.1. Specifically the following has been considered:

- Realign existing overland flow path alongside embankment toe to discharge under bridge/retaining wall and/or move road embankments away from stream
- Optimise bridge opening in detail design so that the upstream and downstream water level differences do not increase by more than 0.5m on land zoned for urban and future urban development.

While the potential operational effects were assessed as moderate these are likely to be significantly reduced with the mitigation measures above. Mitigation measures will be confirmed as part of the Outline Plan process.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

9.5 Conclusions

Positive effects were identified as a result of the new road alignment for bridges at Totara Creek, Ngongetepara Stream. However, the elevated road increased flooding upstream and downstream of

these locations. Detailed design would consider how to optimise the bridge design would ensure that resulting flood effects are minimised.

New proposed culvert crossings at 73 Pomona Road (Chainage 7900) and 146 Motu Road (Chainage 7400) showed a decrease upstream and downstream of the crossings which is a positive effect.

The construction activities for the Alternative State Highway include proposed new culverts, new bridges, new wetlands, and diversion drains or realignment of existing overland flow paths to facilitate these works. No increased risk from flooding was identified during the assessment of construction effects and flood effects will be managed as set out Section 7.1.

The assessment of operational effects found negligible to moderate flood effects during the operational phase of the corridor. There is space within the designation to mitigate this risk by providing overland flow paths or secondary inlets which can be addressed at the detailed design stage. Potential mitigation measures for operational effects have been set out in Section 8.1.

Potential flooding effects can be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in set out in Section 3.2 of this report being met.

10 NoR S2: SH16 Main Road Upgrade

10.1 Project Corridor Features

10.1.1 Catchment Characteristics

The corridor crosses several overland flow paths, unnamed streams and Kumeū River. Existing flood prone areas from AC Geomaps are evident where overland flow paths and streams traverse the corridor.

In addition, the existing 100year ARI flood maps from the latest Kumeū-Huapai catchment model with MPD and existing terrain show flooding at:

- Kumeū River bridge crossings at Chainage 380 and 1730
- Property at 22 Riverhead Rd, Kumeū
- Properties at 550, 573 and 695 State Highway 16, Huapai
- Properties at 9-11, 14, 16 Weza Lane, Huapai
- Properties downstream between Chainage 1200 and 1740, zoned Business – Light Industry Zone; and
- Properties at 68, 74, 395, 399 and 401 Main Road, Huapai.

Key stormwater management assets in NoR S2 include:

- Huapai Reserve North Wet Detention Pond (SAP ID 2000066734)
- Huapai Res Irrigation pond Wet Detention Pond (SAP ID 2000712914)

10.2 Existing and Likely Future Environment

10.2.1 Planning Context

SH16 Main Road is proposed to be upgraded to a 24m urban corridor along the urban extent of SH16 traversing through well-established retail, commercial and residential environs through Kumeū Huapai. This corridor contains a range of business, residential and open space and rural land uses under the AUP:OP (see zoning column in Table 10-1) between the eastern extent of the Kumeū-Huapai township and the western extent of the upgraded corridor (the intersection with the proposed ASH).

Table 10-1 provides a summary of the existing and likely future environment as it relates to the SH16 Main Road Upgrade.

Table 10-1: SH16 Main Road Upgrade Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[7]	Likely Future Environment[8]
Rural	Rural Mixed Rural Zone,	Low	Rural

[7] Based on AUP:OP zoning/policy direction
[8] Based on AUP:OP zoning/policy direction

Environment today	Zoning	Likelihood of Change for the environment[7]	Likely Future Environment[8]
	Rural Countryside Living Zone		
Business	Business (Industrial)	Low	Business (Industrial)
	Business (Local Centre)	Low	Business (Local Centre)
	Business (Mixed Use)	Low	Business (Mixed Use)
Residential	Residential	Low	Residential
Open Space	Open Space – Sport and Active Recreation	Low	Open Space
Undeveloped greenfield areas	Future Urban	High	Urban

Please refer to the AEE for further information on the planning context.

10.3 Proposed works

For NoR S2 the Project involves the widening of the existing 20m wide two-lane urban arterial to a 24m wide corridor with walking and cycling facilities on both sides of the corridor and the realignment of Station Road to form a new signalised intersection with SH16 and Tapu Road.

Other proposed works in NoR S2 which are relevant for the flooding assessment include:

- Construction of three new bridges over Kumeū River
- Construction of new culvert crossings for overland flow paths / streams
- Construction of diversion drains / realignment of overland flow paths
- Construction of stormwater wetlands including upgrade of Huapai Res Irrigation pond Wet Detention Pond (SAP ID 2000712914)

10.4 Assessment of Flooding Effects and Measures to Avoid, Remedy or Mitigate Actual or Potential Adverse Effects

10.4.1 Positive Effects

There are positive effects for Kumeū township downstream of SH16 (see Figure 10-1). This is due to the raised elevation of SH16/RTC which prevents SH16 overtopping in certain places and reduces the flood depth downstream. However, there is an up to moderate effect upstream which can potentially be avoided at detailed design through new or improved crossings in this area.

Figure 10-1: Flood Difference Maps for Strategic Projects

10.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 7 above.

Stream crossings are key sites for potential flooding effects during construction, this includes:

- Kumeū River crossings
- Ahukuramu Stream

10.5 Recommended measures to avoid, remedy or mitigate construction effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes.

The potential flooding effects during construction will be managed through flood risk mitigation measures to be set out in the Construction Environmental Management Plan (CEMP).

All other mitigation measures as set out in Section 7.1 apply.

10.5.1 Assessment of Operational Effects

10.5.1.1 Kumeū River Bridge no 1, 2 and 3

Raising the elevation of the road is exacerbating existing flooding issues in Kumeū town centre (see Section 3.3.1). In order to reduce the effects of flooding to be consistent with the pre-development scenario it is recommended the vertical alignment of SH16 is maintained at the existing level as much as possible. The RTC should still be raised in order to improve resilience for the new road. Where the

road is raised there will be a positive effect associated with increased freeboard for the road and improved flood resilience. With the recommendation to leave SH16 at the current level as much as possible SH16 will still overtop between Kumeū River Bridge and Access Road as it currently does.

10.5.1.2 Kumeū Township

In the existing situation SH16 is predicted to overtop resulting in widespread flooding in the town centre. With the new road alignment water can no longer pass easily over SH16 and into the town centre. The RTC also prevents water passing easily from east to west. As a result of the obstruction, there is a reduction in flood levels north of SH16 and west of Riverhead Road. This area which is positively affected includes the majority of Kumeū township which is downstream of SH16 (see Figure 10-1).

However, due to water being held back by SH16 and RTC there is a minor effect on properties at the junction of SH16 and RTC of up to +0.30m at 7 Main Road, Kumeū (Point SH7). To mitigate this effect there is the potential for further crossings opposite Kumeū District Trotting Club under the RTC to allow water to pass under the elevated alignment. The modelling included an opening at this location, but this opening may need to be larger, or an additional opening provided. This potential mitigation can be provided within the existing designation and a final solution can be confirmed as part of the Outline Plan.

An alternative mitigation was considered which involved acquiring land at this location and lowering the ground level to provide flood attenuation. However, this was not considered feasible due to the flat terrain and the shallow water table.

Mitigation would be confirmed at detailed design stage which would provide more information about the crossings over Kumeū River and its tributaries and the final road alignment.

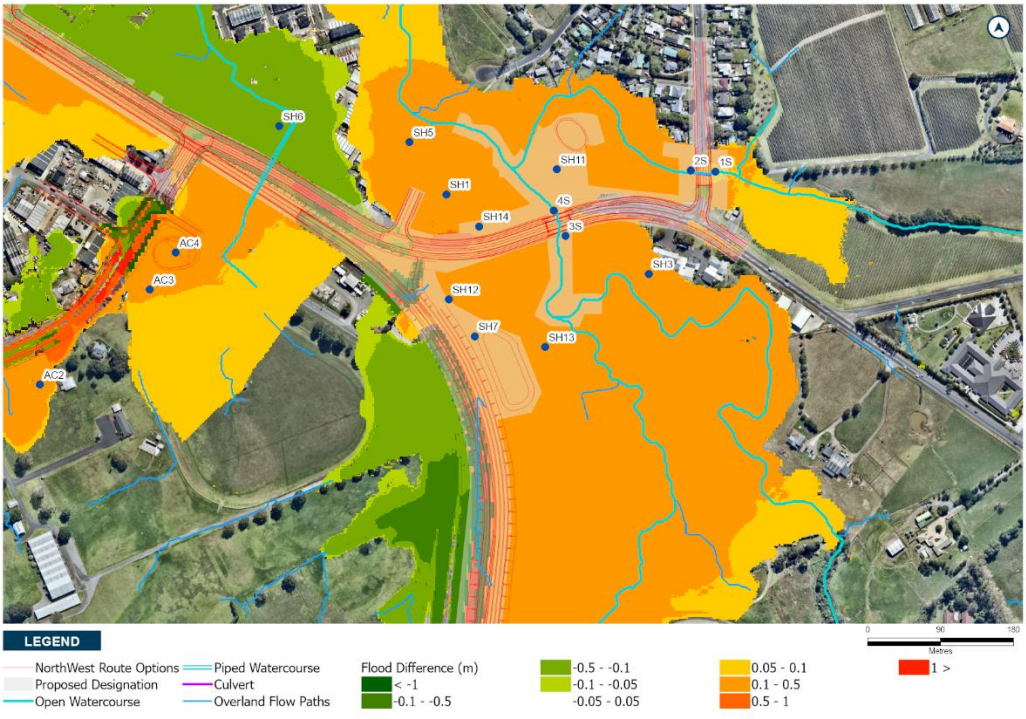

Figure 10-2: Flood Difference Maps for Strategic Projects

10.5.1.3 Foster Road

There is a minor effect at the Ahukuramu Stream bridge (Point 12A and 13A in Figure 10-3) with an increase of +0.09 m. The bridge over the stream should be longer and/or the intersection at Foster Road may need to be altered to provide a wider overland flow path to mimic the existing overland flow path. With a wider opening and increased capacity under the road the effect upstream of SH16 near Foster Road could be minimised. This mitigation is possible within the current designation and a final solution can be addressed at a future stage of design.

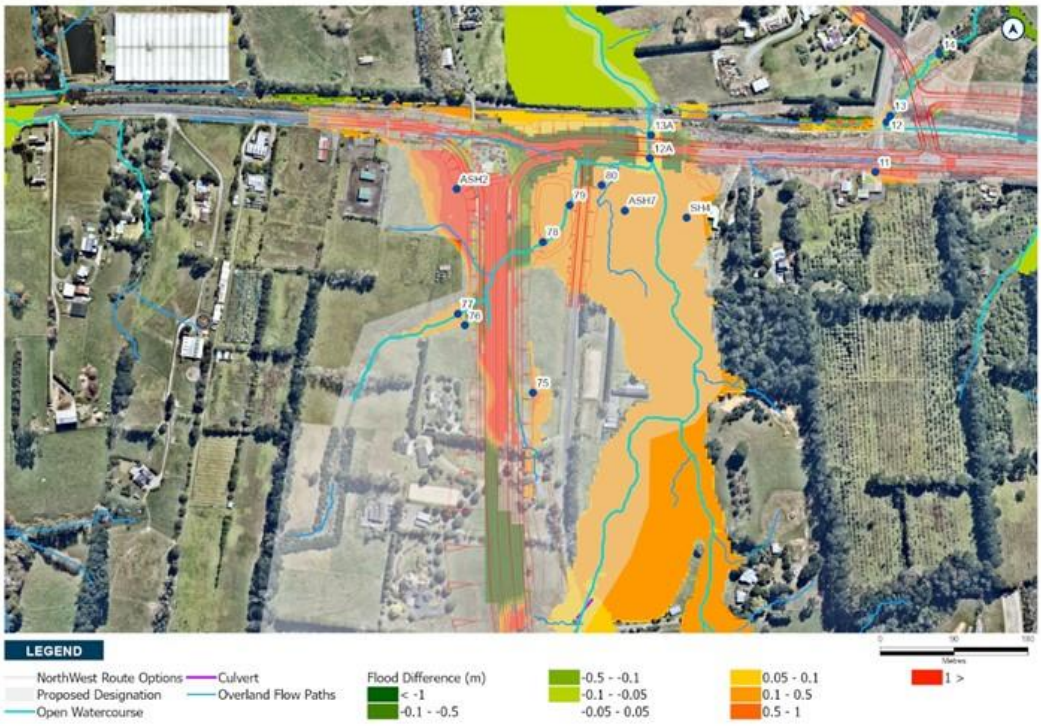

Figure 10-3: Flood Difference Maps for Strategic Projects

10.5.1.4 Main Road Huapai

Huapai Reserve North Wet Detention Pond (SAP ID 2000066734, near Point 25 in Figure 10-4) is not proposed to be upgraded. This pond is not directly impacted by the current alignment, however, may be affected by construction of the new RAMC.

At 587 Main Road, Huapai (Point 29 and 30 in Figure 10-4) there is a moderate effect upstream (+0.79 m) and a positive effect downstream (-0.27 m). This effect could be avoided by increased the culvert size at detailed design to achieve flood neutrality. Specific mitigation will be confirmed during detailed design.

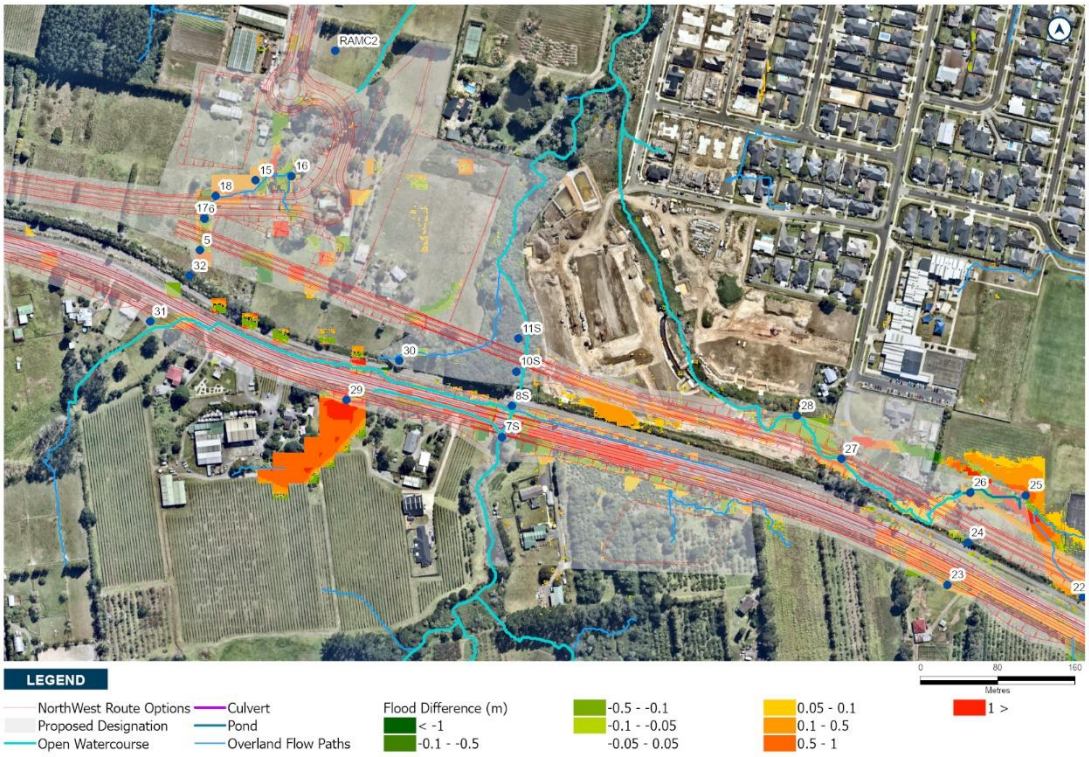

Figure 10-4: Flood Difference Maps for Main Road near proposed Huapai Station

10.5.2 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The potential mitigation measures could be adopted as set out in Section 8.1. Specifically the following has been considered:

- In order to reduce the effects of flooding south-east of Kumeū township it is recommended the vertical alignment of SH16 is maintained at the existing level. The RTC should still be raised in order to improve resilience for the new road.
- Provide sufficient stormwater capacity under RTC to enable water to pass under the elevated alignment

While the potential operational effects were assessed as moderate these are likely to be significantly reduced with the mitigation measures above. Mitigation measures will be confirmed as part of the Outline Plan process.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

10.6 Conclusions

Positive effects were identified as a result of the new road alignment for the three bridges at Kumeū River. However, the elevated road increased flooding upstream and downstream of these locations. Detailed design to optimise the bridge design would ensure that resulting flood effects are negligible.

No increased risk from flooding was identified during the assessment of construction effects and flood effects will be managed as set out Section 7.1.

The assessment of operational effects found negligible to moderate flood effects during the operational phase of the corridor. A range of mitigation measures which might be implemented for operational effects have been set out in Section 8.1. There is space within the designation to mitigate this risk by providing new or upsized crossings with the aim of achieving flood neutrality which can be addressed at the detailed design stage.

Potential flooding effects can be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in set out in Section 3.2 of this report being met.

11 NoR S3: RTC and RAMC; NoR KS: Kumeū Rapid Transit Station and NoR HS: Huapai Rapid Transit Station

11.1 Project Corridor Features

11.1.1 Catchment Characteristics

The Rapid Transit Corridor (**RTC**) and Regional Active Mode Corridor (**RAMC**) crosses several overland flow paths, unnamed streams and major streams namely; Kumeū River, Totara Creek and Ngongetepara Stream. Existing flood prone areas from AC GIS are evident where overland flow paths and streams traverse the corridor.

The existing 100-year ARI flood maps from the latest Kumeū-Huapai catchment model with MPD and existing terrain show flooding at:

- Kumeū River bridge crossing at Chainage 1740
- properties at 993 Waitakere Rd, Kumeū
- properties at 12, 32, 40 and 58 Brookvale Lane, Taupaki

11.2 Existing and Likely Future Environment

11.2.1 Planning Context

The RTC and RAMC form a single, integrated corridor (Note the RAMC only extends to the eastern entrance to Kumeū). This corridor predominately traverses rural land outside of the FUZ, however for assessment purposes it can be split into two sections:

- The **rural section** of the RTC runs from the Brigham Creek Interchange to the entry to Kumeū-Huapai township and is co-located with the RAMC along this section. This rural section traverses land zoned under the AUP:OP as Rural – Countryside Living Zone, with an area zoned as FUZ in Redhills North.

The **urban section** of the RTC runs from northern end of Waitakere Road to Foster Road and is co-located with the proposed SH16 Main Road upgrade[9] along this section. This urban section contains a range of land uses zoned under the AUP:OP as a mix of business zonings between the eastern extent of the Kumeū-Huapai township and Station Road. Table 11-1 below provides a summary of the Northwest existing and likely future environment as it relates to the RTC and the RAMC.

Table 11-1: RTC and RAMC Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[10]	Likely Future Environment[11]
Rural	Rural	Low	Rural

[9] Another Northwest Strategic project – refer to Section **Error! Reference source not found.** of this report

[10] Based on AUP:OP zoning/policy direction

[11] Based on AUP:OP zoning/policy direction

Environment today	Zoning	Likelihood of Change for the environment[10]	Likely Future Environment[11]
Undeveloped greenfield areas	Future Urban	High	Urban
Business	Business (Industrial)	Low	Business (Industrial)
	Business (Local Centre)	Low	Business (Local Centre)
	Business (Town Centre)	Low	Business (Town Centre)
Residential	Residential	Low	Residential
Open Space	Open Space – Informal Recreation Open Space – Sport and Active Recreation	Low	Open Space
Future Urban Zone / Undeveloped greenfield areas	Future Urban	High	Urban

The RTC stations - Kumeū Rapid Transit Station and Huapai Rapid Transit Station - are located in the urban section of the RTC corridors.

Kumeū Station is proposed to be located on land at 299 and 301 Main Road on the western side of a Kumeū River tributary. The land is zoned under the AUP:OP as Business - Town Centre Zone.

An active modes overbridge is proposed across the NAL with active mode connections to:

- The Huapai Triangle crossing land zoned in the AUP:OP as Green Infrastructure Corridor and Residential - Mixed Housing Suburban Zone; and
- Wookey Lane crossing land zoned in the AUP:OP as Green Infrastructure Corridor and Residential - Mixed Housing Suburban Zone; and Business - Light Industry Zone.

Table 11-2: Kumeū Rapid Transit Station Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[23]	Likely Future Environment[24]
Business	Business (Industrial)	Low	Urban
	Business (Town Centre)	Low	Urban
Residential	Residential - Mixed Housing Suburban Zone	Low	Urban
Open Space (located to the north of the	Open Space – Informal Recreation	Low	Open Space

proposed station location)	Open Space – Sport and Active Recreation		

Huapai Station is proposed to be located on land at 29 and 31 Meryl Avenue on the western side of the Ahukuramu. The land is zoned under the AUP:OP as Business - Town Centre Zone. An active modes overbridge is proposed across the NAL and SH16 to FUZ land. Future connections will be determined as part of structure plan process.

Table 11-3: Huapai Rapid Transit Station Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[25]	Likely Future Environment[26]
Residential (located to the east of the proposed station location)	Residential – Single House Zone	Low	Urban
Future Urban Zone / Undeveloped greenfield areas	Future Urban	High	Urban

Please refer to the AEE for further information on the planning context.

11.3 Proposed Works

11.3.1 Rapid Transit Corridor (RTC) and Regional Active Mode Corridor (RAMC)

The RTC is split into the following sections:

- The **rural section** of the RTC runs from the Brigham Creek Interchange to the entry to Kumeū-Huapai township and is co-located with the RAMC along this section. Within the rural section, the RTC requires an extended width to accommodate both the RTC and RAMC.
- The **urbanised section** of the RTC runs from northern end of Waitakere Road to Foster Road and is co-located with the proposed SH16 Main Road upgrade[12] along this section. Within this section, the RTC requires approximately 38m width to locate two FTN rail or lanes, separated active mode facilities and the SH16 Main Road Upgrade.

11.3.2 NoR KS: Kumeū Rapid Transit Station

Kumeū Station is proposed to be located between SH16 Main Road and the NAL, near Matua Road and west of the Kumeu River bridge. The Project provides for a bus services interchange, walking and

cycling access as well as on demand travel (e.g., taxi pick up and drop off). An active mode overbridge will connect the Kumeu Station over NOR S3 RTC.

11.3.3 NoR HS: Huapai Rapid Transit Station

The proposed Huapai Station is located on the northern side of the NAL, at the end of Meryl Avenue. The Project provides for bus services interchange, walking and cycling on demand travel (pick up drop off) as well as park-and-ride. An active mode overbridge will connect the station over the RTC and NAL to the southern side of the FUZ, within the AC Spatial Strategy's indicative town centre.

11.3.4 Other works

Other proposed works in NoR S3 which are relevant for the flooding assessment include:

- Construction of new bridges over Kumeū River, Totara Creek and Ngongetepara Stream.
- Construction of new culvert crossings for overland flow paths / streams
- Construction of diversion drains / realignment of overland flow paths
- Construction of wetlands for RTC project corridor
- Construction of wetlands for RAMC project corridor
- Upgrade of Huapai Res Irrigation pond Wet Detention Pond (SAP ID 2000712914)

11.4 Assessment of Flooding Effects and Measures to Avoid, Remedy or Mitigate Actual or Potential Adverse Effects

11.4.1 Positive Effects

The upgrade of the bridge over Kumeū River (points 10S and 11S in Figure 10-4) provides improvement to flood resilience with adequate freeboard between the 100yr flood level and bridge soffit level >1.2 m. The new bridge allows for water to move more easily under the road and results in minor positive effects upstream and downstream of the crossing.

A positive effect is also associated with the Kumeū River crossing (Point 5S and 6S in Figure 11-1) with a reduction in the flood depth. The bridge also provides greater than 1.2m freeboard. There is also a positive effect at 223 Main Road (Chainage 1600, Point 9S in Figure 11-1) which a reduction in flood level. This reflects the broader positive effects due to a reduction in flooding across the town centre see Section 10.5.1.2.

Figure 11-1: Flood Difference Maps for RAMC

11.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 7 above.

Stream crossings are key sites for potential flooding effects during construction, this includes:

- Kumeū River crossings
- Karure Stream crossing

11.4.3 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes. Various culverts need to be installed or upgraded. There could be increased flood levels or new flow paths created during construction if adequate flow diversions are not provided.

The potential flooding effects during construction will be considered by, and managed through, flood risk mitigation measures to be set out in the Construction Environmental Management Plan (CEMP).

Lay down areas will be confirmed during the construction phase and therefore siting them with respect to flooding constraints should be considered further through the CEMP.

All other mitigation measures as set out in Section 7.1 apply.

11.4.4 Assessment of Operational Effects

11.4.4.1 Rapid Transit Corridor (RTC) and Regional Active Mode Corridor (RAMC)

The new proposed culvert crossing at 623 State Highway 16 (Chainage 4140, Point 31 and 32 in Figure 10-4) shows an increase in the 100year ARI flood level upstream and downstream of the crossing. The level between the design road level centre line and the flood level is ± 1.34m freeboard which is above the 0.5m freeboard required over a culvert. However, the flood difference map shows an increase more than 0.5m upstream which is considered a moderate effect (Point 31 and Point 32 in Figure 10-4). One potential option for mitigation in the upgrading of the culvert to allow more water to pass under the road to decrease the flood level upstream. Final mitigation will be confirmed at detailed design stage.

Karure Stream

The new embankments for NoR S3 are obstructing Karure Stream causing flooding upstream of the crossing, including Point RTC2 (Figure 9-4). Increasing bridge opening to ensure the stream is not obstructed by embankments will avoid the effect. This is possible within the existing designation boundary and a final solution can be confirmed at detailed design stage.

Where the proposed road design runs parallel to the rail line the elevation of both corridors creates an area of ponding (Point RTC 1). Potential mitigation includes the construction and operation of a new culvert crossing under RTC which would avoid this effect by alleviating ponding. The final mitigation will be confirmed at detailed design stage.

11.4.4.2 Kumeū Rapid Transit Station

At the proposed station location (301 Main Road, Huapai, Point RAMC1 in Figure 11-1) there are no flood hazard effects. During detailed design the network for the station will need to confirm no flood hazard effects.

11.4.4.3 Huapai Rapid Transit Station

The new proposed culvert crossing at Chainage 3460 (point 27 and 28 Figure 10-4) shows an increase in the 100yr ARI flood level upstream and downstream of the crossing. The level between the design road level centre line and the flood level is ± 2.65m freeboard which is above the 0.5m freeboard required over a culvert. For a post-development the flood level +0.02m upstream and -0.53m downstream which is a negligible effect upstream and positive effect downstream. The overall effect can be considered positive.

The new proposed culvert crossing at Meryl Avenue Chainage 180 shows an increase in the 100year ARI flood level upstream and downstream of the crossing. The level between the design road level centre line and the flood level is ± 1.08m freeboard which is above the 0.5m freeboard required over a culvert. The flood difference map shows an increase between 0.05m and 0.5m upstream which is considered a minor effect and a decrease downstream which is a positive effect (Point 15 and Point 16 in Figure 11-2). Potential mitigation includes optimising culvert in detailed design to achieve flood neutrality. The final mitigation will be confirmed at detailed design stage.

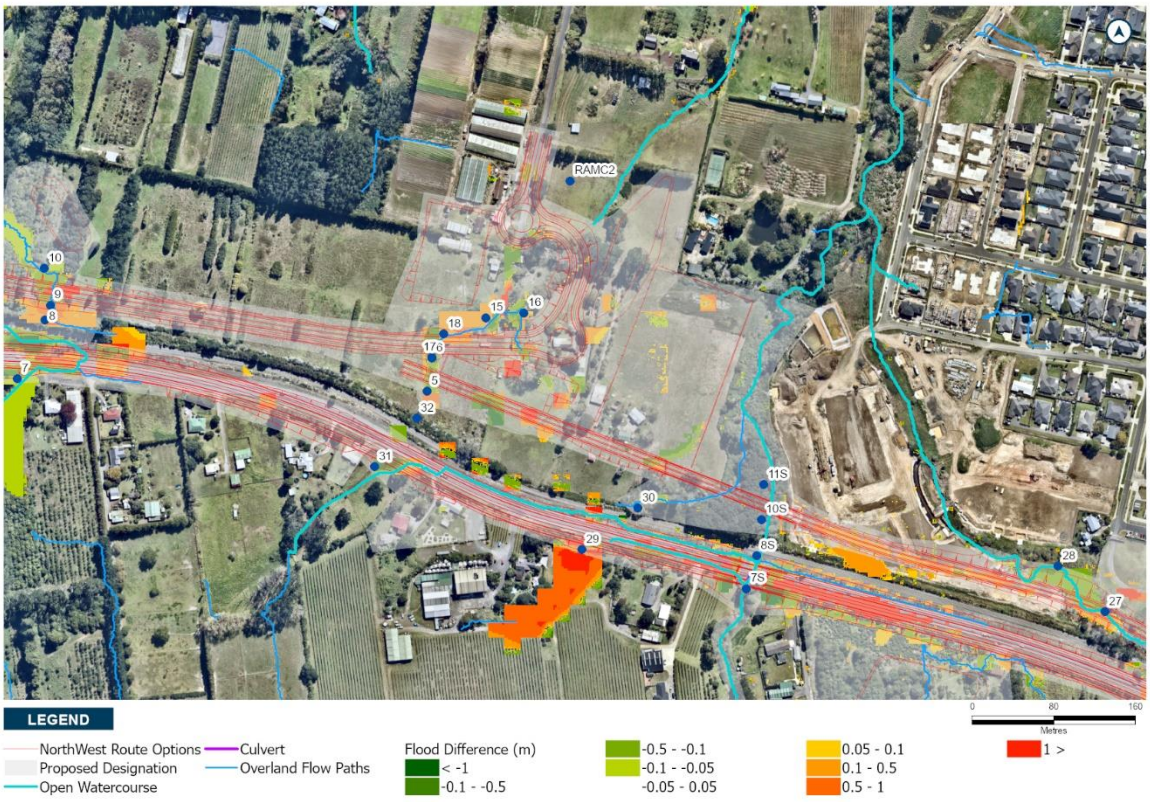

Figure 11-2: Flood Difference Maps for Huapai Station

11.4.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The potential mitigation measures could be adopted as set out in Section 8.1. Specifically the following has been considered:

- Increase bridge opening over Karure Stream to ensure that stream is not obstructed by embankments
- Considering raising the vertical alignment to increase freeboard at Chainage 60
- Install and maintain a new culvert crossing under RTC with new channel alongside the rail corridor to connect to existing network and upgrade existing inlet capacities.
- Design, install and maintain a new culvert crossing under RTC to alleviate ponding at Waitakere Road, Kumeū.

11.5 Conclusions

A positive effect is also associated with the Kumeū River crossings due to an increased freeboard improving resilience of the road and a reduction in flood level upstream and downstream of the crossings.

No increased risk from flooding was identified during the assessment of construction effects and flood effects will be managed as set out Section 7.1.

The assessment of operational effects found minor to moderate flood effects during the operational phase of the corridor. A range of potential mitigation measures for operational effects have been set out in Section 8.1. There is space within the designation to mitigate this risk by providing overland flow paths or secondary inlets which can be addressed at the detailed design stage.

Potential flooding effects can be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in set out in Section 3.2 of this report being met.

12 NoR S4: Access Road Upgrade

12.1 Project Corridor Features

The corridor is mostly on a ridge between Motu Road and Farrand Road and then crosses an unnamed stream and an overland flow path just before Grivelle Street. Existing flood plains and flood prone areas are identified in Auckland GIS.

The existing 100year flood maps from the latest Kumeū-Huapai catchment model with MPD and existing terrain show flooding at properties; 27, 35, 95, 116, 123, 151 and 161 Access Road, Kumeū. Existing flood prone areas from AC GIS are evident next to the corridor.

12.2 Proposed Works

For S4 the project proposes to widen the existing corridor from two vehicle lanes, one per direction, and a small segment with footpaths at the eastern end to include two vehicle traffic lanes, as well as new facilities for walking and cycling.

Other proposed works in NoR S3 which are relevant for the flooding assessment include:

- Construction of a new bridge over unnamed stream at Chainage 1820
- Construction of diversion drains / realignment of overland flow paths
- Construction of four wetlands

12.3 Existing and Likely Future Environment

12.3.1 Planning Context

Access Road/Tawa Road is an existing arterial corridor that runs along the eastern RUB of Kumeū-Huapai.

- The northern side of Access Road is zoned under the AUP:OP as FUZ, with Business – Light Industry Zoning at the north-eastern section of Access Road.
- The southern side of Access Road is predominantly zoned under the AUP:OP as Rural – Countryside Living, with exception to the Kumeū Showgrounds which are zoned as Rural – Mixed Rural Zone are identified as a precinct (I517 Kumeū Showgrounds Precinct) in the AUP:OP.

Table 12-1 below provides a summary of the existing and likely future environment as it relates to Access Road.

Table 12-1: Access Road Upgrade Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[13]	Likely Future Environment[14]
Business	Business (Light Industrial) Zone	Low	Business (Light Industrial)

[13] Based on AUP:OP zoning/policy direction
[14] Based on AUP:OP zoning/policy direction

Environment today	Zoning	Likelihood of Change for the environment[13]	Likely Future Environment[14]
Rural	Rural – Countryside Living Zone Rural – Mixed Rural Zone	Low	Rural
Undeveloped greenfield areas (Future Urban Zone)	Future Urban	High	Urban

Please refer to the AEE for further information on the planning context.

12.4 Assessment of Flooding Effects and Measures to Avoid, Remedy or Mitigate Actual or Potential Adverse Effects

12.4.1 Positive Effects

Existing road at Chainage 1820 overtops during a 100yr flood event. The new bridge over the unnamed stream provides an improvement to flood resilience. The new bridge has a freeboard > 1.2m between the 100yr ARI flood level and bridge soffit level. The 100yr ARI flood difference at the bridge shows there is negligible effect on the water levels upstream and downstream.

12.4.2 Assessment of Construction Effects

As set out in Section 7 flood effects from construction works are not anticipated.

12.4.3 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Flood effects from construction are not anticipated, however, resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes. Where works are in the flood plain it is expected these can be managed through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP).

All other mitigation measures as set out in Section 7.1 apply.

12.4.4 Assessment of Operational Effects

Figure 12-1: Flood Difference Maps for Access Road

12.4.4.1 Unnamed Stream Bridge Crossing

The proposed 120m bridge (refer to points 1C and 2C in Figure 12-1) spans across an unnamed stream with bridge piers set outside the main river channel.

The results for the 100yr ARI pre-development scenario show that the flood level at the location of the proposed bridge structure is RL 24.41m upstream and RL 24.24m downstream. The results for the post-project development scenario show a negligible increase compared to the pre-project development upstream only (+0.01 m). The structure has a freeboard of 1.67m between the 100yr ARI flood level and bridge soffit which is above the 1.2m required freeboard and there are no effects on any nearby buildings. The potential effect of the bridge on flood hazards is therefore considered negligible.

12.4.4.2 Access Road

Positive effects are likely where road's elevation has been raised which will result in the road no longer overtopping. The elevated alignment provides adequate freeboard e.g. Adjacent to 127A Access Road (Chainage 1820-1940, Point 1C and 2C in Figure 12-1).

However, because the raised alignment no longer overtops during the 100year event water is trapped upstream which results in a minor to moderate effect with respect to flood hazard (see points AC1 to AC3 in Figure 12-1). One way this effect can be mitigated by installing diversion drains alongside road to discharge into culvert crossing at Waitakere Rd to enable water to flow from these areas and discharge into the stormwater network. This mitigation is possible within the designation boundary as drains would run parallel to the proposed upgraded road.

12.4.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The potential mitigation measures could be adopted as set out in Section 8.1. Specifically the following has been considered:

- Diversion drains alongside the corridor to realign existing overland flow paths to discharge toward the existing culvert under Waitakere Road

While the potential operational effects were assessed as moderate these are likely to be significantly reduced with the mitigation measures above. Mitigation measures will be confirmed as part of the Outline Plan process.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

12.5 Conclusions

No increased risk from flooding was identified during the assessment of construction effects and flood effects will be managed as set out Section 7.1.

Positive effects were identified Chainage 1820 where the raised elevation will result in the road no longer overtopping and provides adequate freeboard >1.2 m. However, the elevated road alignment currently shows increased flood levels at properties either side of the road.

There was a moderate effect as a result of increased flood levels at open space along the Access Road corridor. One way this effect can be mitigated is by designing, installing and maintaining diversion drains alongside road to discharge into culvert crossing at Waitakere Rd. The final mitigation will be confirmed as part of detailed design.

Potential flooding effects can be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in set out in Section 3.2 of this report being met.

13 Sensitivity Analysis

13.1 NoR S1: Alternative State Highway, including Brigham Creek Interchange

There is an increase in flood level at the following key crossings:

- Totara Creek
- Ngongetepara Stream
- Karure stream
- Unnamed Stream
- Kumeū River

However, at all these crossings there remains adequate freeboard for the 100year event even during a more severe climate change scenario. Any resource consent will be supported by an assessment of the detailed design with respect to flood effects and this will include the relevant climate change scenario. The increased flood effects as a result of increased rainfall under a more severe climate change scenario are noted as a risk. However, this increased risk can be addressed through the mitigation measures described in the report.

13.2 NoR S2: SH16 Main Road Upgrade

There is an increase in flood level at the following key crossings:

- Kumeū River
- Ahukuramu Stream

For a more severe climate change scenario there would no longer be adequate freeboard for the 100year event. However, it is noted that the designation is flexible to allow for the vertical alignment to change during detailed design. Any resource consent will be supported by an assessment of the detailed design with respect to flood effects and this will include the relevant climate change scenario. The increased flood effects as a result of increased rainfall under a more severe climate change scenario are noted as a risk. However, this increased risk can be addressed through the mitigation measures described in the report.

13.3 NoR S3: Rapid Transit Corridor and Regional Active Mode Corridor; NoR KS: Kumeū Rapid Transit Station and NoR HS: Huapai Rapid Transit Station

The key crossings for NoR S3 include Kumeū River. There is an increase in flood effects at this crossing. There remains adequate freeboard for the 100year event even during a more severe climate change scenario. Any resource consent will be supported by an assessment of the detailed design with respect to flood effects and this will include the relevant climate change scenario. The increased flood effects as a result of increased rainfall under a more severe climate change scenario are noted as a risk. However, this increased risk can be addressed through the mitigation measures described in the report.

13.4 NoR S4: Access Road Upgrade

There is one crossing in NoR S4 over an unnamed stream. At this location the effect increases from negligible to moderate. However, there remains adequate freeboard. Any resource consent will be supported by an assessment of the detailed design with respect to flood effects and this will include the relevant climate change scenario. The increased flood effects as a result of increased rainfall under a more severe climate change scenario are noted as a risk. However, this increased risk can be addressed through the mitigation measures described in the report.

14 Conclusion

The assessment of the potential flood effects for the Projects was based on an indicative design of the new road.

There will be a number of positive effects associated with the development particularly where new bridges are proposed which raise the existing road levels reducing the potential for flood levels to overtop the road and reducing flood hazard. Additional positive effects can be realised through upgrades to existing culverts or new culvert crossings to improve overland and stream flow under the roads.

The assessment found that there was unlikely to be additional risk of flood effects during construction as all proposed lay down areas will be outside of the flood plain and overland flow paths. For those areas where there is an increased risk mitigation measures such as carrying out construction works during dry weather and using diversion drains will be adequate to manage this risk.

Potential operational effects included increased flood levels upstream and downstream of crossings and bridges. Some of the effects were assessed as moderate based on an increase in flood level of greater than 0.15m for habitable buildings and 0.5m for general property. These effects are a result of the changing terrain, based on the spatial land take for the new infrastructure, which obstructs existing overland flows and flood plains. These effects are likely overstated as they can be addressed through detailed design of the bridges, culverts and crossings to manage flows upstream and downstream to minimise flooding effects.

There are some stormwater wetlands proposed within or near to the flood plain or which have been found to flood during the 100yr ARI. For these wetlands mitigation is proposed to raise the embankment and install diversion drains for any overland flow paths to reduce the risk of flooding.

A number of management and mitigation measures have been provided to ensure that effects will be adequately managed.

A sensitivity analysis has been undertaken to consider the effects of additional rainfall under a more severe climate change scenario. The sensitivity analysis identified an increased risk of flooding at some locations. However, this increased risk can be addressed through the mitigation measures described in the report.

15 References

Auckland Council (Nov 2011) Stormwater Modelling Specification

Auckland Council GeoMaps (accessed 2021)

SGA flood models, as follows:

Available Models	**Strategic Package Projects within the catchment models**
Kumeū-Huapai Rapid Flood Hazard Assessment	Alternative State Highway, including Brigham Creek Interchange (NoR S1) State Highway Main Road Upgrade (NoR S2) Rapid Transit Corridor and Regional Active Mode Corridor (NoR S3) Access Road Upgrade (NoR S4)
Taupaki Rapid Flood Hazard Assessment	Alternative State Highway, including Brigham Creek Interchange (NoR S1) Rapid Transit Corridor and Regional Active Mode Corridor (NoR S3)
Redhills Rapid Flood Hazard Assessment	Alternative State Highway, including Brigham Creek Interchange (NoR S1) Rapid Transit Corridor and Regional Active Mode Corridor (NoR S3)
Whenuapai Rapid Flood Hazard Assessment	Alternative State Highway, including Brigham Creek Interchange (NoR S1) Rapid Transit Corridor and Regional Active Mode Corridor (NoR S3)

New Zealand Transport Agency (April 2016) NZTA P46 Stormwater Specification

New Zealand Transport Agency (2013) Bridge Manual SP/M/022 third edition

1 Appendix 1 – Flood model results

1.1 NoR S1: Alternative State Highway, including Brigham Creek Interchange

Table 15-1: Alternative State Highway, including Brigham Creek Interchange, summary of flood levels at key crossings

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
Adjacent to 16 – 18 Spedding Road (Chainage 100, Points 14A and 2A in Figure 9-3)	Totara Creek Bridge	Totara Creek Bridge, 30m long Bridge soffit level 16.96m	17.59m upstream, 14.34m downstream Existing road level 18.08m	17.68m upstream, 14.86m downstream	+0.09m upstream, +0.52m downstream	Minor effect upstream, moderate effect downstream Less than 1.2m freeboard
87 Joseph Dunstan Drive (Chainage 3200, Points 15A and 4A in Figure 9-1)	Existing ground level 6.36m	Ngongetepara Stream bridge, 530m long Bridge soffit level 21.75m	9.4m upstream, 9.21m downstream	9.57m upstream, 9.24m downstream	+0.17m upstream, +0.03m downstream	Minor effect upstream, no effect downstream Adequate freeboard
Chainage 2000 (Point 5A and 16A in Figure 9-4)	n/a	Karure stream bridge, 40m long Bridge soffit level 16.83m	13.39m upstream, 12.23m downstream Existing ground level 14.0m	13.97m upstream, 13.86m downstream	+0.58m upstream, +1.63m downstream	Moderate effect upstream and downstream Adequate freeboard
182 Boord Crescent (Chainage 3300, Point 6A and 7A in Figure 9-5)	n/a	Unnamed Stream bridge, 100m long Bridge soffit level 32.16m	29.09m upstream, 29.53m downstream Existing ground level 28.34 m	30.61m upstream, 29.85m downstream	+1.52m upstream, +0.32m downstream	Moderate effect upstream and minor effect downstream Adequate freeboard
Point ASH3 in Figure 9-5	186 Boord Crescent, Kumeū	Building / house, site level RL 28.22m	28.63m	29.39m	-0.24m	Positive
Point ASH4 in Figure 9-5	176 Boord Crescent, Kumeū (Wetland 5)	Open space RL 29.94 m	29.99m	31.21m	+1.22m	Moderate effect

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
Point ASH5 in Figure 9-5	749 Waitakere Road, Kumeū	Open Space, Rural zone, site level RL 32.67 m	33.11m	33.07m	-0.04m	Positive effect
Point ASH6 in Figure 9-5	44 Brookvale Lane, Taupaki	Building / house, site levels; RL 30.51 m	30.59m	31.34m	+0.75m	Moderate effect
191 Pomona Road (Chainage 5900, Points 8A and 9A in Figure 9-7)	Culvert under Pomona Road, size unknown	Bridge over an unnamed Stream and Pomona Road, 120m long Bridge soffit level 43.6 m	38.53m upstream, 37.40m downstream	38.63m upstream, 37.25m downstream	+0.1m upstream, -0.15m downstream	Minor effect upstream, positive effect downstream Adequate freeboard
Point ASH1 in Figure 9-7	170 Pomona Road / 32 Hanham Road, Kumeū	Open Space, Rural zone, site level RL 39.65m	40.34m	41.55m	+1.21m	Moderate effect
Point ASH8 in Figure 9-7	32 Hanham Road, Kumeū	Open space, rural, site level RL 37.63m	38.69 m	40.74 m	+2.05 m	Moderate effect
73 Pomona Road (Chainage 6500, Point 57 and 58 in Figure 9-2)	n/a Existing ground level 46.08 m	(x2) 3500 mm x 1000 mm box culverts Design road CL level 59.78 m	53.63m upstream, 49.75m downstream	52.13m upstream, 49.78m downstream	-0.50m upstream, +0.03m downstream	Positive effect upstream and negligible effect downstream Adequate freeboard
34 Pomona Road (Chainage 7200, Points 10A and 11A in Figure 9-2)	n/a Existing ground level 40.92 m	Kumeū River bridge, 40m long Bridge soffit level 52.89 m	42.31m upstream, 40.46m downstream	42.56m upstream, 40.52m downstream	+0.25m upstream, +0.06m downstream	Moderate effect upstream and minor effect downstream Adequate freeboard
146 Motu Road (Chainage 7400, Point 63 and 64 in Figure 9-2)	n/a	3500 mm x 1000 mm box culvert	46.79m upstream, 42.22m downstream	47.10m upstream, 42.28m downstream	+0.31m upstream, +0.06m downstream	Moderate effect upstream and minor effect downstream

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
62 Foster Road (Chainage 10,000, Point FR1 and FR2 in Figure 9-8)	n/a Existing ground level 15.57 m	Ahukuramu Stream bridge, 320m long Bridge soffit level 25.75 m	20.26m upstream, 19.97m downstream	n/a	n/a	n/a Adequate freeboard
58 Foster Road (Chainage 10,700, Point 71 and 72 in Figure 9-8)	n/a Existing ground level 18.39 m	(x2) 3000 mm x 1000 mm box culverts Design Road CL level 22.79 m	21.04m upstream, 19.49m downstream	21.53m upstream, 19.50m downstream	+0.49m upstream, -0.01m downstream	Moderate effect upstream, positive effect downstream Adequate freeboard
Point ASH2 in Figure 9-8	727 State Highway 16, Huapai	Building / house, site level RL 19.15 m	19.60 m	21.23m	+1.63m	Moderate effect
Point ASH7 in Figure 9-8	23 Foster Road, Huapai	Open space, proposed Wetland 15, top level RL 20.3 m	19.29m	19.46m	+0.17m	Minor effect

1.2 NoR S2: SH16 Main Road Upgrade

Table 15-2: SH16 Main Road upgrade existing and future flood levels at key crossings

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
2-12 Main Road (Riverhead Rd Chainage 160, Point 1S and 2S in Figure 10-2)	1800 mm diameter pipe	1800 mm diameter pipe	24.45m upstream, 23.41m downstream Existing road level 23.87 m	24.57m upstream, 24.52m downstream	+0.12m upstream, +0.11m downstream	Minor effect upstream and downstream
12 Weza Lane (Chainage 380, Point 3S and 4S in Figure 10-2)	Kumeū River bridge Existing road level 24.9 m	Kumeū River bridge no 1, 30m long Bridge soffit level RL 26.41 m	22.53m upstream, 22.51m downstream	25.27m upstream, 24.58m downstream	+0.26m upstream, +0.07m downstream	Moderate effect upstream and minor effect downstream Adequate freeboard
Point SH1 in Figure 10-2	16 Main Road, Kumeū Current flooding issues	Building / house, site level RL 24.27m	23.37 m	24.44 m	+1.07m	Moderate effect
Point SH5 in Figure 10-2	11 Weza Lane, Huapai	Building / house, site level RL 23.09 m	23.17 m	24.33 m	+1.16m	Moderate effect
Point SH6 in Figure 10-2	64 Main Road, Kumeū	Building / house, site level RL 22.55 m	22.52 m	23.79 m	+1.27m	Moderate effect
Point SH7 in Figure 10-2	7 Main Road, Kumeū	Open space, proposed Wetland 2, top level RL 22.0 m	24.09 m	25.34 m	+0.30 m	Moderate effect
Point SH11 in Figure 10-2	550 Main Road Kumeū Within flood plain	Open space for proposed Wetland 1, top level RL 23.6m	22.47 m	24.52 m	+0.18 m	Moderate effect

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
Point SH12 in Figure 10-2	7 Main Road, Kumeū Current flood prone area	Building / house, site level RL 24.23m	24.08 m	25.25 m	+1.17m	Moderate effect
SH13 in Figure 10-2	7 Main Road, Kumeū	Building / house, site level RL 24.32 m	24.26 m	25.46 m	+1m	Moderate effect
SH14 in Figure 10-2	16 Main Road, Kumeū	Building, site level RL 23.63m	23.66 m	25.09 m	+1.43m	Moderate effect
583 Main Road, Huapai (Chainage 3760, Point 7S and 8S in Figure 10-2)	Kumeū River bridge Existing road level 21.4 m	Kumeū River bridge no 3, 30m long Bridge soffit level RL 23.42 m	21.75m upstream, 21.94m downstream	21.72m upstream, 21.63m downstream	-0.03m upstream, -0.31m downstream	Positive effect upstream and downstream Adequate freeboard
(SH16 chainage 500, Point 12A and 13A in Figure 10-3)	Ahukuramu Stream bridge Existing road level 17.08m	Ahukuramu Stream bridge, 30m long Bridge soffit level 21.20 m	19.34m upstream, 19.33m downstream	19.43m upstream, 19.42m downstream	+0.09m upstream, +0.09m downstream	Minor effect upstream and downstream Adequate freeboard
587 Main Road, Huapai (Point 29 and 30 in Figure 10-4)	n/a	750 mm diameter pipe	24.50m upstream, 20.89m downstream	25.29m upstream, 20.61m downstream	+0.79m upstream, -0.27m downstream	Moderate effect upstream and positive effect downstream

1.3 NoR S3: Rapid Transit Corridor and Regional Active Mode Corridor; NoR KS: Kumeū Rapid Transit Station and NoR HS: Huapai Rapid Transit Station

Table 15-3: Rapid Transit Corridor existing and future flood levels at key crossings

Chainage	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
Chainage 1730 (point 5S and 6S in Figure 11-1)	Kumeū River bridge Existing road level 20.66m	Kumeū River bridge No 2, 30m long Bridge soffit level RL 23.34 m	21.84m upstream, 21.79m downstream	21.88m upstream, 21.57m downstream	+0.04m upstream, -0.22m downstream	Negligible effect upstream, positive effect downstream Adequate freeboard
223 Main Road, Huapai (Chainage 1600, Point 9S in Figure 11-1)	n/a	Kumeū River bridge, 210m long Bridge soffit level 23.05 m	21.86m upstream	21.76m upstream	-0.1m	Positive effect Adequate freeboard
Point RAMC1 in Figure 11-1	301 Main Road, Huapai	Proposed station location, site level 23.49 m	24.93 m	24.93 m	0.0m	n/a
Point RAMC2 in Figure 10-4	11 Meryl Ave, Huapai	Open space, proposed Wetland 14, top level RL 22.6 m	24.24 m	24.24 m	0.0m	n/a
50 Gilbransen Road, Huapai (Chainage 3460, Point 27 and 28 in Figure 10-4)	n/a Existing ground level 23.45 m	(x2) 3500 mm x 1000 mm box culverts Design road CL level 27.26 m	24.36m upstream, 23.58m downstream	24.61 upstream, 23.63m downstream	+0.25m upstream, +0.05m downstream	Minor effect upstream, negligible effect downstream
623 State Highway 16 (Chainage 4140, Point 31 and 32 in)	Unknown	4000 mm x 1000 mm box culvert Design road CL level 30.93 m	29.87 m upstream, 25.78 m downstream Existing road CL level 30.50 m	29.70 m upstream, 26.17 m downstream	+0.67 m upstream, +0.27 downstream	Moderate effect upstream, minor effect downstream

Chainage	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
29 Meryl Ave, Huapai (Chainage 3760-3880, Point 10S and 11S in Figure 10-4)	n/a	Kumeū River bridge, 120m long Bridge soffit level RL 21.95m	19.94m upstream, 19.64m downstream Existing ground level 19.18 m	19.93m upstream, 19.62m downstream	-0.01m upstream, -0.02m downstream	Positive effect upstream and downstream Adequate freeboard
32 Meryl Ave, Huapai (Chainage 4140, Point 5 and 6 in Figure 10-4)	n/a	2000 mm x 1000 mm box culvert Design road Cl level 29.45 m	25.39m upstream, 24.67m downstream	26.08m upstream, 25.16m downstream	+0.69m upstream, +0.49m downstream	Positive effect upstream and minor effect downstream Adequate freeboard
32 Meryl Ave, Huapai (Chainage 60, Point 17 and 18 in Figure 10-4)	n/a	2000 mm x 1000 mm box culvert Design road CL level 25.55 m	24.67m upstream, 24.48m downstream	25.16m upstream, 24.80m downstream	+0.49m upstream, +0.32m downstream	Minor effect both upstream and downstream Adequate freeboard
31 Meryl Ave, Huapai (Meryl Ave Chainage 180, Point 15 and 16 in Figure 10-4)	n/a Existing ground level 24.06 m	2000 mm x 1000 mm box culvert Design road CL level 25.82m	24.44m upstream, 22.25m downstream	24.75m upstream, 22.34m downstream	+0.31m upstream, -0.09m downstream	Minor effect upstream and positive effect downstream
Point RTC2 in Figure 10-4	Lot 1, Joseph Dunstan Drive, Taupaki	Karure Stream crossing, Open space, site level RL 17.67 m	18.13m	19.87 m	+1.74 m	Moderate effect
Point RTC1 in Figure 9-5	Part Taupaki Block Waitakere Road, Kumeū, site level RL 30.79 m	Open Space between Rail and RTC	31.41	32.74 m	+0.55 m	Moderate effect

1.4 NoR S4: Access Road Upgrade

Table 15-4: Access Road upgrade existing and future flood levels at key crossings

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100year flood level (RL) pre-development	100year flood level (RL) post-development	Level difference for 100year flood	Potential effect without mitigation
Adjacent to 127A Access Road (Chainage 1820-1940, Point 1C and 2C in Figure 12-1)	Culvert, size unknown Existing road level RL 23.8 m	Unnamed stream bridge, 120m long Bridge soffit level RL 26.04 m	24.36m upstream, 24.73m downstream	24.37m upstream, 24.23m downstream	+0.01m upstream, -0.04m downstream	Negligible effect upstream, positive effect downstream Adequate freeboard
Point AC1 in Figure 12-1	95 Access Road, Kumeū	Building / house/driveway, site level RL m	27.92	28.06 m	+0.16 m	Moderate effect
Point AC2 in Figure 12-1	35 Access Road, Kumeū	Building / house/driveway, site level RL m	26.80	27.01 m	+0.22 m	Moderate effect
Point AC3 in Figure 12-1	27 Access Road, Kumeū	Building, site level	23.59	24.64 m	+0.12 m	Minor effect

2 Appendix 2 – Sensitivity Analysis results

2.1 NoR S1: Alternative State Highway, including Brigham Creek Interchange

Table 15-5: Consideration of sensitivity at key crossings identified NoR S1

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change between V2 and V3	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
Adjacent to 16 – 18 Spedding Road (Chainage 100, Points 14A and 2A in Figure 9-3)	Totara Creek Bridge	Totara Creek Bridge, 30m long Bridge soffit level 16.96 m	17.68m upstream, 14.86m downstream	17.74m upstream, 15.49m downstream	+0.06m upstream, +0.63m downstream	Minor effect upstream, moderate effect downstream Less than 1.2m freeboard
87 Joseph Dunstan Drive (Chainage 3200, Points 15A and 4A in Figure 9-1)	n/a	Ngongetepara Stream bridge, 530m long Bridge soffit level 21.75 m	9.57m upstream, 9.24m downstream	10.03m upstream, 9.75m downstream	+0.46m upstream, +0.51m downstream	Moderate effect upstream and downstream Adequate freeboard
Chainage 2000 (Point 5A and 16A in Figure 9-4)	n/a	Karure stream bridge, 40m long Bridge soffit level 16.83 m	13.97m upstream, 13.86m downstream	14.09m upstream, 13.96m downstream	+0.12m upstream, +0.10m downstream	Moderate effect upstream and downstream Adequate freeboard
182 Boord Crescent (Chainage 3300, Point 6A and 7A in Figure 9-5)	n/a	Unnamed Stream bridge, 100m long Bridge soffit level 32.16 m	30.61m upstream, 29.85m downstream	31.11m upstream, 30.24m downstream	+0.50m upstream, +0.39m downstream	Moderate effect upstream and minor effect downstream Adequate freeboard
Point ASH3 in Figure 9-5	186 Boord Crescent, Kumeū	Building / house, site level RL 28.22 m	29.39 m	29.75 m	+0.36 m	Moderate effect

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change between V2 and V3	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
Point ASH4 in Figure 9-5	176 Boord Crescent, Kumeū (Wetland 5)	Open space RL 29.94 m	31.21 m	31.81 m	+0.60 m	Moderate effect
Point ASH5 in Figure 9-5	749 Waitakere Road, Kumeū	Open Space, Rural zone, site level RL 32.67 m	33.06 m	33.09 m	+0.03 m	Positive effect
Point ASH6 in Figure 9-5	44 Brookvale Lane, Taupaki	Building / house, site levels; RL 30.51 m	31.34 m	31.92 m	+0.58 m	Moderate effect
191 Pomona Road (Chainage 5900, Points 8A and 9A in Figure 9-7)	Culvert under Pomona Road, size unknown	Bridge over an unnamed Stream and Pomona Road, 120m long Bridge soffit level 43.6 m	38.63m upstream, 37.25m downstream	38.83m upstream, 37.56m downstream	+0.20m upstream, +0.31m downstream	Moderate effect upstream, minor effect downstream Adequate freeboard
Point ASH1 in Figure 9-7	170 Pomona Road / 32 Hanham Road, Kumeū	Open Space, Rural zone, site level RL 39.65 m	41.55 m	41.76 m	+0.21 m	Moderate effect
Point ASH8 in Figure 9-7	32 Hanham Road, Kumeū	Open space, rural, site level RL 37.63 m	40.74 m	41.03 m	+0.29 m	Moderate effect
73 Pomona Road (Chainage 6500, Point 57 and 58 in Figure 9-2)	n/a Existing ground level 46.08 m	(x2) 3500 mm x 1000 mm box culverts Design road CL level 59.78 m	52.13m upstream, 49.78m downstream	51.23m upstream, 49.81m downstream	+0.10m upstream, +0.03m downstream	Minor effect upstream and positive effect downstream Adequate freeboard
34 Pomona Road (Chainage 7200, Points 10A and 11A in Figure 9-2)	n/a Existing ground level 40.92 m	Kumeū River bridge, 40m long	42.56m upstream, 40.52m downstream	42.78m upstream, 40.64m downstream	+0.20m upstream, +0.12m downstream	Moderate effect upstream and downstream

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change between V2 and V3	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
		Bridge soffit level 52.89 m				Adequate freeboard
146 Motu Road (Chainage 7400, Point 63 and 64 in Figure 9-2)	n/a	3500 mm x 1000 mm box culvert	47.10m upstream, 42.28m downstream	47.30m upstream, 42.43m downstream	+0.20m upstream, +0.15m downstream	Moderate effect upstream and positive effect downstream
58 Foster Road (Chainage 10,700, Point 71 and 72 in Figure 9-8)	n/a Existing ground level 18.39 m	(x2) 3000 mm x 1000 mm box culverts Design Road CL level 22.79 m	21.53m upstream, 19.50m downstream	22.07m upstream, 20.72m downstream	+0.54m upstream, +1.22m downstream	Moderate effect upstream and downstream Adequate freeboard
Point ASH2 in Figure 9-8	727 State Highway 16, Huapai	Building / house, site level RL 19.15 m	21.23 m	21.33 m	+0.10 m	Moderate effect
Point ASH7 in Figure 9-8	23 Foster Road, Huapai	Open space, proposed Wetland 15, top level RL 20.3 m	19.46 m	20.67 m	+1.21 m	Moderate effect

2.2 NoR S2: SH16 Main Road Upgrade

Table 15-6: Consideration of sensitivity at key crossings identified NoR S2

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
2-12 Main Road (Riverhead Rd Chainage 160, Point 1S and 2S in Figure 10-2)	1800 mm diameter pipe	1800 mm diameter pipe	24.57m upstream, 24.52m downstream	24.97m upstream, 24.97m downstream	+0.40m upstream, +0.45 m downstream	Moderate effect upstream and downstream
12 Weza Lane (Chainage 380, Point 3S and 4S in Figure 10-2)	Kumeū River bridge	Kumeū River bridge no 1, 30m long Bridge soffit level RL 26.41 m	25.27m upstream, 24.58m downstream	25.65m upstream, 25.03m downstream	+0.38m upstream, +0.46m downstream	Moderate effect upstream and minor effect downstream Adequate freeboard
Point SH1 in Figure 10-2	16 Main Road, Kumeū	Building / house, site level RL 24.27m Current flooding issues	24.44 m	24.87 m	+0.44m	Moderate effect
Point SH5 in Figure 10-2	11 Weza Lane, Huapai	Building / house, site level RL 23.09 m	24.33 m	24.73 m	+0.40 m	Minor effect
Point SH6 in Figure 10-2	64 Main Road, Kumeū	Building / house, site level RL 22.55 m	23.79 m	24.25 m	+0.46 m	Minor effect
Point SH7 in Figure 10-2	7 Main Road, Kumeū	Open space, proposed Wetland 2, top level RL 22.0 m	25.34 m	25.70 m	+0.36 m	Moderate effect
Point SH11 in Figure 10-2	550 Main Road Kumeū	Open space for proposed Wetland 1, top level RL 23.6m	24.52 m	24.97 m	+0.45 m	Moderate effect

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
		Within flood plain				
Point SH12 in Figure 10-2	7 Main Road, Kumeū	Building / house, site level RL 24.23m Current flood prone area	25.25 m	25.58 m	+0.32 m	Moderate effect
SH13 in Figure 10-2	7 Main Road, Kumeū	Building / house, site level RL 24.32 m	25.46 m	25.84 m	+0.38 m	Moderate effect
SH14 in Figure 10-2	16 Main Road, Kumeū	Building, site level RL 23.63m	25.09 m	25.52 m	+0.44 m	Moderate effect
583 Main Road, Huapai (Chainage 3760, Point 7S and 8S in Figure 10-2)	Kumeū River bridge	Kumeū River bridge no 3, 30m long Bridge soffit level RL 23.42 m	21.72m upstream, 21.63m downstream	22.67m upstream, 22.66m downstream	+0.96m upstream, +1.03m downstream	Moderate effect upstream and downstream Inadequate freeboard
(SH16 chainage 500, Point 12A and 13A in Figure 10-3)	Ahukuramu Stream bridge Existing road level 17.08m	Ahukuramu Stream bridge, 30m long Bridge soffit level 21.20 m	19.43m upstream, 19.42m downstream	20.62m upstream, 20.60m downstream	+1.19m upstream, +1.18m downstream	Minor effect upstream and downstream Inadequate freeboard
587 Main Road, Huapai (Point 29 and 30 in Figure 10-4)	n/a	750 mm diameter pipe	25.29m upstream, 20.61m downstream	25.44m upstream, 20.68m downstream	+0.16m upstream, +0.07m downstream	Moderate effect upstream and positive effect downstream

2.3 NoR S3: Rapid Transit Corridor and Regional Active Mode Corridor; NoR KS: Kumeū Rapid Transit Station and NoR HS: Huapai Rapid Transit Station

Table 15-7: Consideration of sensitivity at key crossings identified NoR S3, KS and HS

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
Chainage 1730 (point 5S and 6S in Figure 11-1)	Kumeū River bridge Existing road level 20.66m	Kumeū River bridge No 2, 30m long Bridge soffit level RL 23.34 m	21.88m upstream, 21.57m downstream	22.28m upstream, 22.24m downstream	+0.40m upstream +0.67m downstream	Moderate effect upstream and downstream Adequate freeboard
223 Main Road, Huapai (Chainage 1600, Point 9S in Figure 11-1)	n/a	Kumeū River bridge, 210m long Bridge soffit level 23.05 m	21.76m upstream	22.32m	0.56m	Moderate effect
Point RAMC1 in Figure 11-1	301 Main Road, Huapai	Proposed station location, site level 23.49 m	24.93 m	24.93 m	+0.0m	n/a
Point RAMC2 in Figure 10-4	11 Meryl Ave, Huapai	Open space, proposed Wetland 14, top level RL 22.6 m	24.24 m	24.27 m	+0.03m	Negligible effect
50 Gilbransen Road, Huapai (Chainage 3460, Point 27 and 28 in Figure 10-4)	n/a	(x2) 3500 mm x 1000 mm box culverts Design road CL level 27.26 m	24.61 upstream, 23.63m downstream	24.70 upstream, 23.72m downstream	+0.09m upstream, +0.09m downstream	Minor effect upstream and downstream
29 Meryl Ave, Huapai (Chainage 3760-	n/a	Kumeū River bridge, 120m long	19.93m upstream, 19.62m downstream	20.18m upstream, 19.84m downstream	+0.25m upstream, +0.22m downstream	Moderate effect upstream and downstream

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
3880, Point 10S and 11S in Figure 10-4)		Bridge soffit level RL 21.95m				Adequate freeboard
32 Meryl Ave, Huapai (Chainage 4140, Point 5 and 6 in Figure 10-4)	n/a	2000 mm x 1000 mm box culvert Design road CI level 29.45 m	26.08m upstream, 25.16m downstream	26.28m upstream, 25.42m downstream	+0.20m upstream, +0.20m downstream	Minor effect upstream and moderate effect downstream Adequate freeboard
32 Meryl Ave, Huapai (Chainage 60, Point 17 and 18 in Figure 10-4)	n/a	2000 mm x 1000 mm box culvert Design road CL level 25.55 m	25.16m upstream, 24.80m downstream	25.38m upstream, 25.02m downstream	+0.22m upstream, +0.22m downstream	Moderate effect both upstream and downstream Adequate freeboard
31 Meryl Ave, Huapai (Meryl Ave Chainage 180, Point 15 and 16 in Figure 10-4)	n/a Existing ground level 24.06 m	24.44m upstream, 22.25m downstream	24.75m upstream, 22.34m downstream	24.97m upstream, 22.48m downstream	+0.22m upstream, +0.10m downstream	Moderate effect upstream and positive effect downstream
Point RTC2 in Figure 10-4	Lot 1, Joseph Dunstan Drive, Taupaki	Karure Stream crossing, Open space, site level RL 17.67 m	19.87 m	19.95 m	+0.08 m	Moderate effect
Point RTC1 in Figure 9-5	Part Taupaki Block Waitakere Road, Kumeū	Open Space between Rail and RTC, site level RL 30.79 m	32.74 m	32.77 m	+0.03 m	Moderate effect

2.4 NoR S4: Access Road Upgrade

Table 15-8: Consideration of sensitivity at key crossings identified NoR S4

Location	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	2.1° temperature change	3.8° temperature change	Flood level change	Change in potential effect without mitigation
			100yr flood level (RL) post-development	100yr flood level (RL) post-development		
Adjacent to 127A Access Road (Chainage 1820-1940, Point 1C and 2C in Figure 12-1)	Culvert, size unknown Existing road level RL 23.8 m	Unnamed stream bridge, 120m long Bridge soffit level RL 26.04 m	24.37m upstream, 24.23m downstream	24.70m upstream, 24.56m downstream	+0.32m upstream, +0.34m downstream	Moderate effect upstream and downstream
Point AC1 in Figure 12-1	95 Access Road, Kumeū	Building / house/driveway, site level RL 27.72 m	28.06 m	28.11 m	+0.05 m	Moderate effect
Point AC2 in Figure 12-1	35 Access Road, Kumeū	Building / house/driveway, site level RL 26.73 m	27.01 m	27.07 m	+0.06 m	Moderate effect
Point AC3 in Figure 12-1	27 Access Road, Kumeū	Building, site level 23.18m	24.64 m	24.96 m	+0.32 m	Moderate effect