TE TUPU NGĀTAHI
SUPPORTING GROWTH

North West Redhills Riverhead Assessment of Flooding Effects

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Version 1

WAKA KOTAHI
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Abbreviations

Acronym/Term	Description
AC	Auckland Council
AEE	Assessment of Effects on the Environment
ARI	Average Recurrence Interval
ASH	Alternative State Highway
AT	Auckland Transport
AUP:OP	Auckland Unitary Plan Operative in Part
BCI	Brigham Creek Interchange
CC	Climate change
CEMP	Construction Environmental Management Plan
FTN	Frequent Transit Network
FULSS	Future Urban Land Supply Strategy
FUZ	Future Urban Zone
MfE	Ministry for the Environment
MPD	Maximum Probable Development
NAL	North Auckland Line
NoR	Notice of Requirement (under the Resource Management Act 1991)
PWV	Precipitable water vapour
RCP	Representative Concentration Pathways
RL	Reduced level
RMA	Resource Management Act 1991
RTC	Rapid Transit Corridor
RAMC	Regional Active Mode Corridor
RUB	Rural Urban Boundary
SG	Te Tupu Ngātahi Supporting Growth
SH16	State Highway 16
Te Tupu Ngātahi	Te Tupu Ngātahi Supporting Growth
Waka Kotahi	Waka Kotahi NZ Transport Agency

Glossary of Acronyms / Terms

Acronym/Term	Description
AT	Auckland Transport an Auckland Council controlled organisation.
Auckland Council	Means the unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010.
Dry Pond	A permanent pond that is normally dry but during rainfall events temporarily stores stormwater runoff to control discharges. Dry ponds provide limited water quality treatment.
Flood difference map	The difference between the pre-development and post-development flood levels as shown on the map
Freeboard	An allowance above the modelled flood level, be it road level or other features (e.g. existing floor level). For buildings freeboard shall be measured from the top water level to the finished floor level. The relevant design manual shall be referred to for the appropriate freeboard and method of calculation.
Lay down areas	An area that has been cleared for the temporary storage of materials and equipment and may include site compounds, stockpiles, sediment retention ponds.
MPD	Maximum Probable Development according to the AUP:OP zonings
Pre-development	Prior to construction of the Project
Post-development	After construction of the Project
Redhills Riverhead Assessment Package	Two Notices of Requirement (for Don Buck Road and Coatesville-Riverhead Road) and one alteration to an existing designation (Fred Taylor Drive) for the Redhills Riverhead Package of Projects for Auckland Transport.
Stormwater Wetland	Constructed wetlands that temporarily store runoff and support conditions suitable for the growth of wetland plants. Stormwater wetlands provide enhanced water quality treatment of stormwater runoff through vegetation uptake, retention and settling.
Terrain	An elevation model which includes the ground levels based on 2016 LiDAR and the concept design ground levels.
Wet Pond	A permanent pond that has a standing pool of water and provides water quality treatment, and storage of stormwater runoff to reduce the peak water volume from a rainfall event and provide downstream erosion protection.

1 Executive Summary

This report provides an assessment of flood risks associated with the construction, operation and maintenance of the Projects that comprise the Redhills Riverhead Assessment Package.

Flooding is a natural hazard and has therefore been considered as part of the Redhills Riverhead Assessment Package Notices of Requirement. The works required for the Redhills Riverhead Assessment 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 mitigated 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 risk 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;
- effects to existing habitable buildings / infrastructure and potential future effects on upstream and downstream properties.

Methodology

The assessment of flooding effects for the Redhills Riverhead Assessment 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 100 year 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 to understand the increased risk of greater climate change impacts.
- Producing flood level maps for pre-development and post-development scenarios and flood difference maps to show the change in flood levels and extents (greater than 50 mm) as a result of the Project.
- Inspection and review of flood difference maps at key locations such as bridges and where there are noticeable changes in flood extents or flood levels.

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 event using 10% of the total roading impervious catchment area (proposed and existing) in accordance with Auckland Council and Waka Kotahi guidance[1,2]. Note for existing roads being widened this allows for greater impervious area than the road widening alone.

[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)

The assessment considers that flooding effects will be subject to further assessment at a detailed design stage. It is expected that coordination and integration of the corridor design with future urban zone (FUZ) development will be undertaken to confirm and mitigate potential future adverse effects.

Positive Effects

There is the potential for a number of positive effects associated with the projects. These include where the existing road levels will be raised, 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 proposed project corridor. The scale of these effects will be determined at detailed design stage. Water quality treatment allowances will result in reduced environmental impacts as the total road area, and not just the added 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 RE1: Don Buck Road FTN Upgrade

There is no additional risk of flooding expected as the corridor is located on a ridgeline and in an area that has already been developed i.e. does not have FUZ. The project design includes adequate stormwater attenuation and treatment for the additional impervious area from the widened road which will also minimise any additional risk of flooding and improve water quality.

NoR RE2: Fred Taylor Drive FTN Upgrade (alteration to existing designation 1433)

There is a minor risk of flooding at points FT1 and FT2 outside of the Project area. This risk is due to an existing flood issue however the widening of the road corridor may increase flood levels on the western side of the corridor. In order to minimise flood effects, it is recommended that the overland flow path is realigned and upgrades to existing culverts are investigated at the detailed design stage with the aim of achieving flood neutrality.

There is a minor risk at point FT3 where the proposed corridor upgrade intercepts this flood plain. It is recommended that realignment of the overland flow path is reviewed at the detailed design stage to minimise or mitigate the potential effect.

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 R1: Coatesville-Riverhead Highway Upgrade

The raising of the Coatesville-Riverhead Highway will increase freeboard at a number of points along the road. This will result in positive effects by reducing the risk of the road flooding (specifically at Chainage 320, Chainage 700, Chainage 1040 Chainage 1940). Detailed design should confirm if any additional cross drainage is required to achieve flood neutrality.

The road currently overtops during the 100 year flood event and there is a minor risk of flooding at points CR1, CR2 and CR3. Mitigation measures include providing a new channel with an inlet structure west of the corridor and to upgrade the existing pipe network to allow more flow through to minimise or mitigate the potential flood effect. At point CR4 there is a positive effect from the redirection of stormwater through the new inlet/pipe, however there is a moderate increase at Point CR5 as a result of this change. The moderate effect can be mitigated by providing new diversion drains alongside road to discharge into the new inlet and pipe that flows into the open channel to the east.

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

The sensitivity analysis for the potential increased rainfall due to climate change found there was a slight change to the identified flood effects at key locations under a more severe climate change scenario (3.8 degree temperature change). However, no additional mitigation is required as it is anticipated these effects can be mitigated as set out above.

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.

The operational flood risks are classified as minor to moderate. Operational impacts will aim to be resolved during detailed design by optimising the design of culverts to minimise flood effects upstream and downstream of culvert 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 North West Redhills and Riverhead Local Arterials Notices of Requirement (**NoRs**) for Auckland Transport (**AT**) (the "**Redhills Riverhead 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 North West area of Auckland.

This report assesses the flooding effects of the North West Redhills Riverhead Assessment Package identified in Figure 4-1 and Table 2-1 below.

Refer to the Assessment of Effects on the Environment (AEE) for a more detailed project description.

Table 2-1: North West Redhills Riverhead Assessment Package – Notices of Requirement and Projects

Notice	Project
NoR RE1	Don Buck Road FTN Upgrade
NoR RE2	Fred Taylor Drive FTN Upgrade (alteration to existing designation 1433)
NoR R1	Coatesville-Riverhead Highway Upgrade

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 Redhills Riverhead Assessment Package. Its purpose is to inform the AEE that accompanies the Redhills Riverhead 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 Redhills Riverhead Assessment Package on the existing and likely future environment as it relates to flooding effects and recommends measures that may be implemented to minimise, 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 Redhills Riverhead Assessment Package area;
b) Identify and describe the actual and potential flooding effects of each Project corridor within the Redhills Riverhead Assessment Package;
c) Recommend measures as appropriate to minimise, remedy or mitigate actual and potential flooding effects (including any conditions/management plan required) for each Project corridor within the Redhills Riverhead Assessment Package; and
d) Present an overall conclusion of the level of actual and potential flooding effects for each Project corridor within the Redhills Riverhead 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 Redhills Riverhead Assessment Package as it relates to stormwater,
c) Identification and description of the existing and likely future flooding environment;
d) Description of the actual and potential positive effects of the Project;
e) Description of the actual and potential adverse flooding effects of construction of the Project;
f) Description of the actual and potential adverse flooding effects of operation of the Project;
g) Recommended measures to minimise, 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. 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 Riverhead models were used to assess the flood water levels and extents of the existing (pre-development) terrain.

It should be noted the existing terrain (based on AC 2016 LiDAR) 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 100 year 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 risk 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. 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 designation boundary.

The proposed condition requires 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.

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 100 year ARI flood levels (with allowances for full development according to the AUP:OP zonings with associated imperviousness 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:

- Auckland Unitary Plan Operative in Part
- Auckland Council GIS resources (Auckland GeoMaps)
- Design Drawings
- Flood maps created by the SG 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.

3.4 Flood Modelling

3.4.1 Stormwater Catchment Overview

The projects are situated within the Whenuapai, Redhills, Riverhead and Massey stormwater catchments as shown in Figure 3-1.

The Whenuapai catchment is approximately 1,931 ha and drains by numerous creeks and streams, including Brigham Creek, Totara Creek and Waiarohia Stream. The Redhills catchment is approximately 1,366 ha and drains by the Waiteputa and Ngongetepara Streams. The Massey

catchment is approximately 914 ha and drained by Momutu Stream, Manutewhau and Rarawaru Streams. The Riverhead catchment is approximately 1,299 ha and drains mainly by Rangitopuni Stream and smaller unnamed streams. The receiving environment for the Whenuapai, Redhills, Massey and Riverhead catchments is the upper reaches of the Waitemata Harbour.

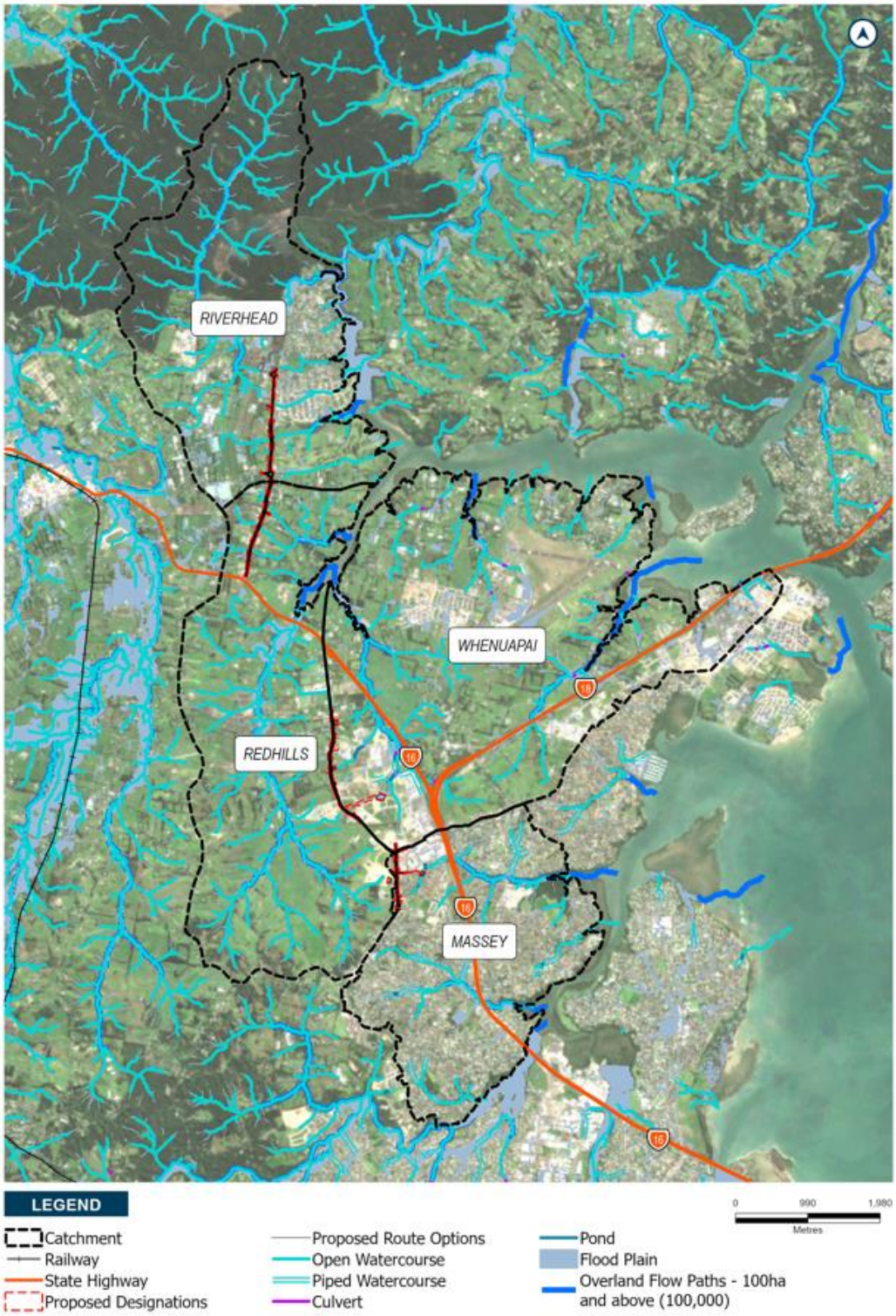

Figure 3-1: Existing 100 year ARI flood pain for Whenuapai, Massey, Riverhead and Redhills catchments (Auckland Council GIS)

3.4.2 Modelling Parameters

Auckland Council have produced Whenuapai, Redhills and Riverhead Rapid Flood Hazard Assessment catchment models which were adapted for this assessment (the models).

The Massey catchment flood model, which covers NoR RE1 (Don Buck Road FTN Upgrade), has not been used for this assessment as the NoR RE1 corridor is located on a ridge, in an area that is already developed, and no increased flooding risk is anticipated from either change in terrain or impacts on crossings.

To assess the flooding effects of the Project on the Whenuapai, Redhills and Riverhead catchments two scenarios were considered for NoR RE2 Fred Taylor Drive FTN Upgrade (alteration to existing designation 1433) and NoR R1 Coatesville-Riverhead Highway Upgrade.

The two scenarios modelled for the assessment of effects are:

Scenario 1: pre-development

- Future 100 year ARI rainfall event with 2.1°C of warming and future land-use without the project in place

Scenario 2: post-development

- Future 100 year ARI rainfall event with 2.1°C of warming 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

- Future 100 year ARI rainfall event with 3.8°C of warming and future land-use without the project in place

Scenario 4: post-development increased climate change

- Future 100 year ARI rainfall event with 3.8°C of warming and future land-use with the project in place

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

The models include the existing roads and existing culverts where the culverts are 600mm or greater and details could be located. In the models existing culverts < 600 mm diameter are considered to be fully blocked although larger culverts are considered to be fully working. This approach is a refinement of the AC rapid flood hazard modelling approach where pipes smaller than 1,200mm are excluded from the model. The reason for selecting 600mm is that the risk of blockage is much greater.

New culverts have been added to convey flows at existing overland flow paths that are crossed by new road alignments 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.

New bridges are incorporated into the model by leaving a gap in the terrain to replicate the bridge opening. Piers are not modelled specifically.

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 climate change by comparing the results of 2.1°C of warming to 3.8°C of warming see Section 12.

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 addressed at detailed design stage.

Table 3-1: Flooding effects assessment criteria

Effect	**More vulnerable uses e.g. residential dwellings**	**Less vulnerable uses e.g. open space, road corridors, commercial and industrial buildings**
Positive	A reduction in flood level	A reduction in flood level
Negligible	Less than 0.05 m	Less than 0.05 m
Minor	0.05 m to 0.5 m	0.05 m to 0.15 m
Moderate	Greater than 0.5 m	Greater than 0.15 m

For more vulnerable land uses, including dwellings, if less than 0.5 m freeboard is available there is a greater risk of damage to property. The effects of properties identified as potentially at risk of flooding considers the flood water level only. Surveyed floor levels of the existing habitable buildings are not available and should be done during the detailed design stage.

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

Waterway Structure	Situation	Freeboard	
		Measurement Points	Level (m)
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 models do 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 3.4.6). However, the models do account for the increased impervious area as a result of development within the FUZ area.

Hence, the models' output incorporates a high 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 anticipated that coordination and integration of the corridor design with FUZ development will be required to confirm and address potential future effects. Mitigation measures in the future detailed design will reflect the actual development in the FUZ areas. See Section 3.4.6 for more detail of the limitations of this assessment.

3.4.6 Model Limitations

NoR RE2 Fred Taylor Drive FTN Upgrade (alteration to existing designation 1433) and NoR R1 Coatesville-Riverhead Highway Upgrade have upstream and / or downstream catchments which contain FUZ. The modelled scenarios use imperviousness assumptions associated with the future land use(s) shown in the Auckland Plan. However, it is possible that significant change in the catchments may take place before or shortly after the corridor is constructed. Therefore, it is anticipated that further modelling will be required during the corridor detailed design phase to take account of catchment characteristics at that time.

Rapid Flood Hazard Assessment models have a relatively coarse terrain grid and do not include stormwater drainage pipes smaller than 600mm diameter. 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.

Generally NoRs for the Redhills and Riverhead Assessment Packages are located on elevated terrain (ridgelines) and it is unlikely that upgrades to existing culverts will be required. However, any new or upgraded culverts will be confirmed at the detailed design stage and will take into account matters such as consent requirements, asset owner requirements, level of service, stream simulation design, fish passage and possible blockage.

The Massey catchment flood model, which covers NoR RE1 was not built. The pre-development model was not considered necessary as the corridor is located on a ridgeline and does not include flood plain or flood prone areas. A post-development flood model was not considered necessary to assess the effects as the area has already been developed i.e. does not have FUZ, therefore no significant changes in topography which would result in increased flooding risk are anticipated. The preliminary design has considered stormwater attenuation for the additional impervious area of the widened road (see Section 3.5).

3.4.7 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 12 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 on 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 risk have been identified. Further mitigation at these locations has been included where necessary to encourage flood resilience.

In the future it is possible there may be different requirements for climate change, however, at this time a pragmatic approach has been taken and the sensitivity analysis has been prepared to better understand the risk of climate change and enable decision makers to respond to this.

[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.

3.5 Stormwater 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 Redhills Riverhead Assessment Package Overview

An overview of the Redhills Riverhead Assessment Package is provided in Figure 4-1 below.

Figure 4-1: Redhills and Riverhead Assessment upgrades

A summary of the Redhills Riverhead Assessment Package projects is provided in Table 4-1 below.

Table 4-1: Redhills Riverhead Assessment Package Project Summary

Corridor	NOR	Description	Requiring Authority
Don Buck Road FTN Upgrade	RE1	Upgrade of Don Buck Road corridor to a 30m wide four-lane cross-section providing bus priority lanes and separated active mode facilities on both sides of the corridor.	Auckland Transport
Fred Taylor Drive FTN Upgrade	RE2	Upgrade of Fred Taylor Drive corridor to a 30m wide four-lane cross-section providing bus priority lanes and separated active mode facilities on both sides of the corridor.	Auckland Transport
Coatesville-Riverhead Highway Upgrade	R1	Upgrading the southern section of the corridor to a 33m two-lane low speed rural arterial cross-section with active mode facilities on the western side; and Upgrading the northern section of the corridor to a 24m two-lane urban arterial cross-section with active mode facilities 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 . 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 below and discussed in more detail in Section 8. There will be a minor effect for NoR RE2 and a minor up to moderate effect for NoR R1.

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 RE1	n/a	n/a	No more than 0.05 m increase in flood level, Negligible up to minor effect
NoR RE2	FT1 (Figure 10-1) Building/ house/ driveway, FUZ	+0.13 m increase in flood level, Minor effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	FT2 (Figure 10-1) Open area, FUZ	+0.24 m increase in flood level, Minor effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	FT3 (Figure 10-1) Building/ house/ driveway, FUZ	+0.12 m increase in flood level, Minor effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
NoR R1	Coatesville Riverhead Highway south of Moontide Road (Chainage 700, points 15 and 16 Figure 11-1) Road corridor	-0.06 m upstream, +0.07 m downstream, Positive effect upstream, minor effect downstream Design road level is outside of flood plain	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Coatesville Riverhead Highway north of Brigham Lane (Chainage 320, points 17 and 18 in Figure 11-1) Road corridor	-1.65 m upstream, -0.10 m downstream, Positive effect Design road level is outside of flood plain	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Point CR1 (Figure 11-2) Building/ house/ driveway, FUZ	+0.20 m increase in flood level, Minor effect	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
	Point CR2 (Figure 11-2) Open area, FUZ	+0.19 m increase in flood level, Minor effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Point CR3 (Figure 11-2) Road corridor	+0.20 m increase in flood level, Minor effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Point CR4 (Figure 11-3) Road corridor	+1.16 m increase in flood level, Negligible effect as new road level predicted to have +0.01m flood depth	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Point CR5 (Figure 11-3) Road corridor	+1.05 m increase in flood level, Moderate effect	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Coatesville Riverhead Highway south of Short Road (Chainage 1940, points 11 and 12 Figure 11-4) Road corridor	-1.09 m upstream, +0.20 m downstream Positive effect upstream and minor effect downstream Design road level is outside of flood plain	No more than 0.05 m increase in flood level, Negligible up to minor effect
	Coatesville Riverhead Highway north of Moontide Road (Chainage 1040, points 13 and 14 Figure 11-5) Road corridor	0.39 m upstream, -0.12 m downstream Moderate effect Design road level is outside of flood plain	No more than 0.05 m increase in flood level, Negligible up to minor effect

6 Positive Effects

The positive effects for projects are those where the predicted 100year 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 NoR R1. NoR RE2 does not have any identified positive flooding effects.

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. The elevated alignment will increased freeboard along Coatesville Riverhead Highway at north of Brigham Lane (Chainage 320), south of Moontide Road (Chainage 700), north of Moontide Road (Chainage 1040and south of Short Road (Chainage 1940).

The projects create the opportunity to improve existing culvert capacities and/or provide new culvert crossings to improve ponding and stream flow in the area. The final design will be subject to further flood modelling during the detailed design stage aimed at achieving flood neutrality.

7 Construction Effects

Construction effects apply to the entire project, however are more likely at locations within or adjacent to overland flows or flood prone areas. The proposed construction works which could result in flooding effects include:

- Construction of new culvert crossings or upgrading of existing culvert crossings;
- Installation of diversion drains / realignment of existing overland flow paths;
- Construction of new attenuation ponds or upgrading of existing attenuation ponds, and;
- Temporary use of lay down areas.

The potential effects of these are:

- Bulk earthworks to complete the contouring for new landscape features e.g. attenuation ponds and new or upgraded culverts require a dry works area and can alter overland flow paths or generate erosion and sediment effects;
- The siting of attenuation ponds within an existing overland flow path can obstruct runoff and result in flows being diverted towards existing properties due to the need for embankments.

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

7.1 Recommended Measures to Minimise, Remedy or Mitigate Construction Effects

The management and mitigation measures for construction effects are outlined below:

General

- Carrying out earthworks during the summer / dry months to reduce the risk of flooding;
- Locating lay down areas outside of predicted overland flow paths and flood plains;
- Managing the overland flow paths to make sure flows are not diverted toward existing buildings or properties;
- Construction Environmental Management Plans (CEMP) be developed prior to construction by an experienced Stormwater Engineer and shall mitigate the effects of temporary works, earthworks, storage of materials, temporary diversion and drainage on flow paths, flow levels and velocities. Including (but not limited to):
    - Siting construction yards and stockpiles outside the predicted flood plains;
    - 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 extreme flood events;
    - Actions to take in response to heavy rain warnings which may include reducing the conveyance of materials and plant that are considered necessary to be stored or sited within the predicted flood plain or significant overland flow path.

Construction of new and existing culvert crossings and stormwater wetlands and ponds:

- 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 to allow flows to be maintained while new culverts and ponds 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 (> 600mm in size) a working clearance of ±20m from the upstream extent and ±15m from the downstream extents should be provided.

8 Operational Effects

There are a range of operational effects particularly from proposed crossings. The model is based on an indicative design which will respond to the future environment and it may be that some of these structures are modified in the future. Future detailed design will be subject to a separate flooding assessment at the resource consent stage. For the project the assessment of operational flooding effects considered:

- New culvert crossings (≥ 600 mm diameter);
- Areas where the new road embankment encroaches onto predicted flood plain and flood prone land;
- The potential 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 on a different alignment;
- 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 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 Minimise, 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. This is where existing predicted overland flow paths run parallel to the proposed roads and do not cross under the road;
- 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 or 0.05m for existing floors at risk of flooding;
- 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;

- Integrating development design requirements for FUZ upstream and downstream of the proposed corridor.

9 NoR RE1: Don Buck Road FTN Upgrade

9.1 Project Corridor Features

9.1.1 Catchment Characteristics

The corridor is located on a ridgeline and as such there are no visible stream crossings or major flood plains along the corridor. No flood prone areas are evident on Auckland Council GIS resources.

9.2 Existing and Likely Future Environment

9.2.1 Planning Context

The land adjacent to Don Buck Road is comprised of various business, residential and open space zoning. The following outlines the key elements of the planning context for the Don Buck Road FTN Upgrade:

- The eastern side of Don Buck Road above Westgate Drive is zoned under the AUP:OP as Business – Light Industry. To the south of Westgate Drive, the eastern side of Don Buck Road contains an Open Space – Community Zone (occupied by Massey Leisure Centre), with the remaining land zoned as Residential – Mixed Housing Zone.
- The western side of Don Buck Road is within the I610 Redhills Precinct and is predominantly zoned Residential – Mixed Housing Urban, with a portion of land in the northern section of the corridor zoned Residential – Terraced Housing and Apartment Buildings Zone (**THAB**). Land further to the west of Don Buck Road forms part of the Redhills Precinct.

Table 9-1 below provides a summary of the existing and likely future environment as it relates to the Don Buck Road FTN Upgrade.

Table 9-1: Don Buck Road FTN Upgrade Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[4]	Likely Future Environment[5]
Business	Business (Industrial)	Low	Business
Residential	Residential – Mixed Housing Urban Zone Residential – Terraced Housing and Apartment Zone	Low	Residential
Open Space	Open Space – Community Zone	Low	Open Space

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

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

9.3 Proposed works

One stormwater catchment is created along the transport corridor and runoff from the catchment flows into two proposed stormwater wetlands, as shown in the Indicative Design Drawings for treatment and attenuation.

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

9.4.1 Positive Effects

The corridor lies on a ridgeline and away from any existing flood prone areas and no increased flooding risks are anticipated. The proposed road is mostly above its existing alignment, therefore improving freeboard and reducing any potential flood risk.

9.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 7 above.

However it is noted the proposed upgraded Stormwater Wetland 2 is located within flood plain and overland flow path.

9.4.3 Recommended Measures to Minimise, 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 considered by, and 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 in Section 7.1 apply.

9.4.4 Assessment of Operational Effects

No modelling results are provided, as described in section 3.4.6. The corridor is located on a ridgeline and crosses no major overland flow paths or streams and is outside any floodplain or flood prone areas therefore no operational effects are anticipated.

Figure 9-1: 100 year ARI flood difference map for Don Buck Road

9.4.5 Recommended Measures to Minimise, Remedy or Mitigate Operational Effects

No specific measures have been identified as there is a minimal risk of flooding. The detailed design will still need to demonstrate compliance with the outcomes set out in Section 3.2 as required by the designation conditions.

9.5 Conclusions

The corridor is located on a ridgeline and is not subject to risk of flooding. No potential flooding risks during operations are anticipated.

10 NoR RE2: Fred Taylor Drive FTN Upgrade

10.1 Project Corridor Features

10.1.1 Catchment Characteristics

The project corridor runs predominantly on a ridgeline with several overland flow paths and streams draining west of the corridor towards Ngongetepara Stream and east of the corridor towards Totara Creek. An existing minor culvert crossing drains the low-lying area alongside the road at Chainage 1040.

Existing flood prone areas have been identified from Auckland Council GIS at Chainages 1500 and 2520. A flood prone area and an existing 375 mm diameter pipe crossing are at Chainage 1040. The existing overland flow path in this location is shown to flow alongside the road towards Hailes Road.

Flood plains are evident on both sides of the corridor with additional flood prone areas (depression areas with a single outlet) further downstream of the catchment on the eastern side.

10.2 Existing and Likely Future Environment

10.2.1 Planning Context

The existing Fred Taylor Drive corridor runs through a mix of residential and industrial land uses.

The northern section of Fred Taylor Drive is within the Redhills North FUZ, with an area of land zoned under the AUP:OP as Open Space – Sport and Active Recreation Zone (Fred Taylor Park) adjacent the road corridor. The southern section of Fred Taylor Drive is zoned under the AUP:OP as THAB zone on the western side, and forms part of the I610 Redhills Precinct. The eastern side is zoned Business – Light Industry Zone and Business – Mixed Use Zone and forms part of the I615 Westgate Precinct.

Table 10-1 below provides a summary of the existing and likely future environment as it relates to the Fred Taylor Drive FTN Upgrade.

Table 10-1: Fred Taylor Drive FTN Upgrade Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[6]	Likely Future Environment[7]
Business	Business (Light Industrial)	Low	Business
	Business (Mixed Use)	Low	
Residential	Residential – Terraced Housing and Apartment Zone	Low	Residential
Open Space	Open Space – Sport and Active Recreation	Low	Open Space

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

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

Environment today	Zoning	Likelihood of Change for the environment[6]	Likely Future Environment[7]
Undeveloped greenfield areas	Future Urban	High	Urban

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

10.3 Proposed works

Along NoR RE2 it is proposed to widen Fred Taylor Drive to accommodate a 30m wide four-lane FTN arterial with separated walking and cycling facilities[8].

Other proposed works in NoR RE2 which are relevant for the flooding assessment include:

- Construction of diversion drains / realignment of existing overland flow path running parallel with the existing and proposed road alignment;
- Construction of three Stormwater Ponds, one of which is the upgrade of an existing pond;
- Upgrade of an existing channel towards Stormwater Pond 1.

Additional flood storage using attenuation ponds is required for NoR RE2 to attenuate and discharge the 100 year ARI pre-development peak flow. Stormwater catchments and features are shown in the Indicative Design Drawings.

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

10.4.1 Assessment of Construction Effects

Potential construction effects have been described in Section 7 above.

It is noted the proposed upgraded Stormwater Wetland 1 is located within flood plain and overland flow path.

10.4.2 Recommended Measures to Minimise, 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).

[8] The Fred Taylor Drive FTN Upgrade has an interdependency with the North West Strategic Transport Network, therefore the portion of Fred Taylor Drive north of Hailes Road forms part of the upgrade to Brigham Creek Interchange.

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.

10.4.3 Assessment of Operational Effects

10.4.3.1 160 – 168 Fred Taylor Drive

An existing 375 mm diameter culvert crossing is located on Fred Taylor Drive at Chainage 1040 between Northside Drive and Hailes Road which is undersized and an existing overland flow path will be compromised by the corridor upgrade (Figure 10-1). Further assessment of the crossing suggests the wider corridor may increase flood levels on the western side of the corridor due to the predicted flood plain being within the road formation footprint.

This has identified impacts on existing buildings outside of the proposed designation:

- Point FT1 is predicted to be affected by an increased flood level of +0.13 m under a post-development scenario and this effects is considered minor.
- Point FT2 is predicted to be affected by an increased flood level of +0.24 m under a post-development scenario and this effects is considered minor.

The flood effects could be mitigated by upgrading the existing culvert at Chainage 1040 and creating a new overland flow path alongside the corridor. The designation boundary at Chainage 1040 includes sufficient area to enable mitigation to be undertaken and a final solution can be addressed at a future stage of design.

While this area is currently undeveloped it is zoned as FUZ and the model (and the assessment) allowed for this area to be developed for residential use according to the AUP:OP. New housing and would be required to include a minimum freeboard which would also ensure flood effects to future properties would be minimised.

10.4.3.2112 Fred Taylor Drive

Point FT3 (Figure 10-1) at 112 Fred Taylor Drive (Chainage 1800) is anticipated to have an increased flood depth of +0.12, this effect is considered minor. Flooding is the result of the terrain with a local setpoint which does not drain away.

Mitigation could include providing drainage at this location e.g. at the toe of the batter for the proposed new road alignment at detailed design or by regrading this location so the water can escape. This is possible within the current designation boundary and a final solution can be addressed at a future stage of design.

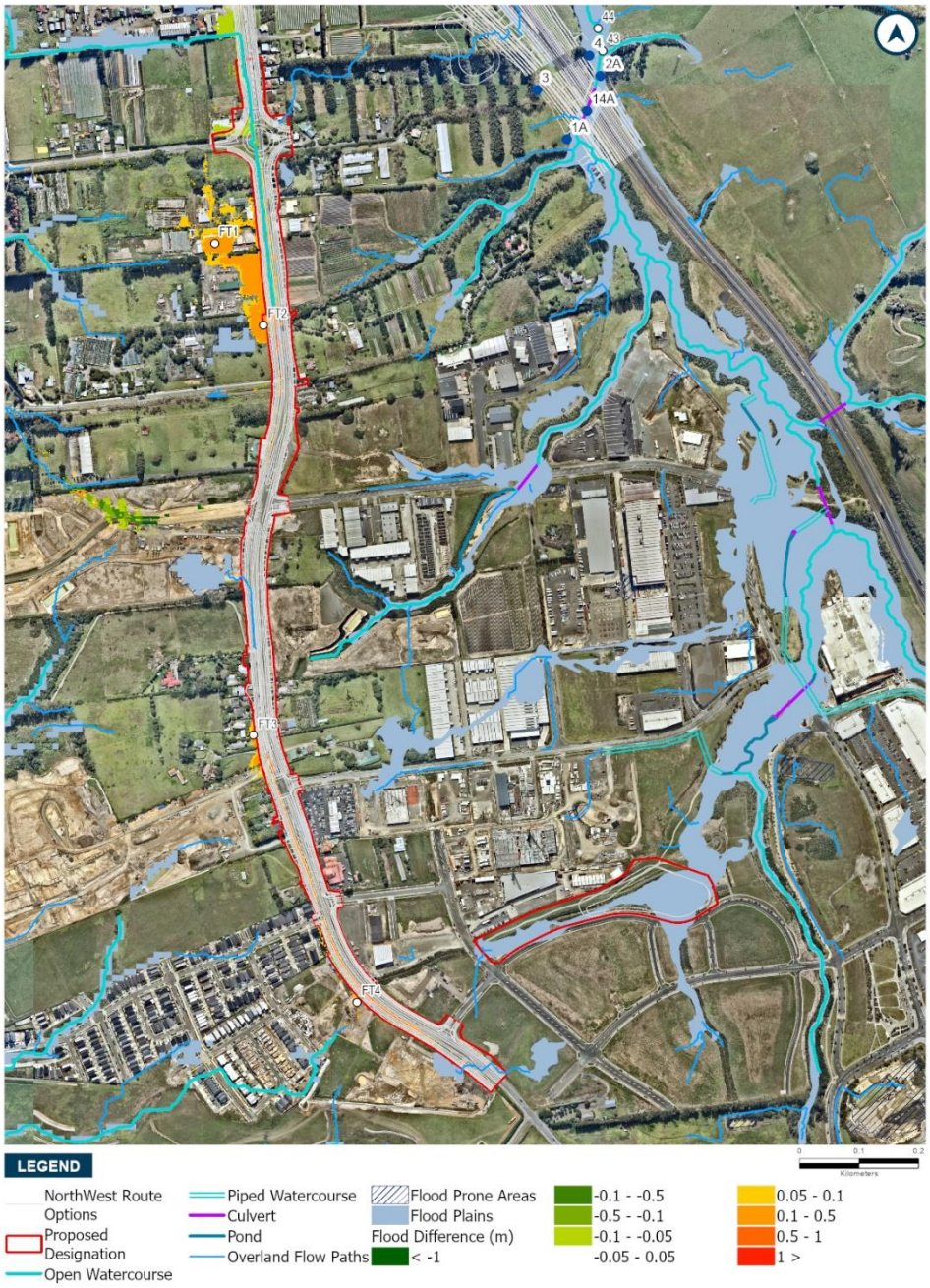

Figure 10-1: 100 year ARI flood difference map for Fred Taylor Drive

10.4.4 Recommended Measures to Minimise, 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 existing culvert size at Chainage 1040 and include the realignment of an overland flow path running alongside the corridor

- At Chainage 1800 provide a way for water to escape from the local setpoint through additional drainage infrastructure or regrading at this location.

While the potential operational effects were assessed as moderate these are likely to be significantly reduced with the mitigation measures above. Further assessment at the detailed design stage can be used to confirm the potential effects following mitigation.

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.

10.5 Conclusions

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

The assessment of operational effects found a minor to moderate flood risk to properties in the NoR RE2 Fred Taylor Drive FTN Upgrade FTN Upgrade. There is space within the designation to mitigate this risk by diverting flows or realigning overland flow paths and / or upgrading the existing culverts 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 R1: Coatesville-Riverhead Highway Upgrade

11.1 Project Corridor Features

11.1.1 Catchment Characteristics

The corridor crosses five unnamed streams that drain east towards the estuaries. Existing predicted flood plain and flood prone areas from Auckland GIS are evident where overland flow paths and streams traverse the road. Existing flood plain and flood prone areas are evident upstream of the unnamed stream crossings.

There is no information available regarding culverts at Coatesville Riverhead Highway north of Moontide Road (Chainage 1040), south of Moontide Road (Chainage 700) and north of Brigham Lane (Chainage 320). There is a 1200 mm culvert at Coatesville Riverhead Highway south of Short Road (Chainage 1940). The unknown culverts are not included in the model which will affect the results.

11.2 Existing and Likely Future Environment

11.2.1 Planning Context

The southern section of Coatesville-Riverhead Highway from SH16 to Short Road runs through rural land uses predominantly zoned under the AUP:OP as Rural – Mixed Rural Zone on both sides of the existing corridor. The northern section (close to and within the Riverhead township) runs through land zoned as Residential – Single House Zone and to the east and future urban zoned land on the west.

Table 11-1 below provides a summary of the North West existing and likely future environment as it relates to the Coatesville-Riverhead Highway Upgrade.

Table 11-1: Coatesville-Riverhead Highway Existing and Likely Future Environment

Environment today	Zoning	Likelihood of Change for the environment[9]	Likely Future Environment[10]
Rural	Rural	Low	Rural
Residential	Residential	Low	Residential
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

The Coatesville-Riverhead Highway Upgrade Project involves:

- Upgrading the southern section of the corridor to a 33m two-lane low speed rural arterial with active mode space on the western side; and

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

- Upgrading the northern section of the corridor to a 24m two-lane urban arterial with walking and cycling facilities on both sides of the corridor.

The project includes upgrades to the intersections with Old Railway Road and Riverhead Road and is expected to tie in with a future roundabout at SH16 as part of the Waka Kotahi SH16 Safety Improvements Project.

Other proposed works in NoR R1 which are relevant for the flooding assessment include:

- Construction of a new stormwater wetland
- Construction of a new culvert crossings at Chainages 320, 700, 1040 and 1940

Additional flood storage using attenuation ponds is required for NoR RE2 to attenuate and discharge the 100 year ARI pre-development peak flow. Stormwater catchments and features are shown in the Indicative Design Drawings.

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

11.4.1 Positive Effects

There are a number of positive effects due to the raising of the vertical alignment which provides additional freeboard and reduces the flood hazard risk for users of the road. These locations include:

- Coatesville Riverhead Highway south of Short Road (Chainage 1940, Points 11 and 12 in Figure 11-1) the road currently overtops during the 100 year ARI flood event. For the proposed road the centreline level is lifted to RL 21.49 m and the flood level is reduced to RL 19.33 m which increases the freeboard to +2.16 m.
- Coatesville Riverhead Highway north of Moontide Road (Chainage 1040, Points 13 and 14 in Figure 11-1) the road currently overtops during the 100 year ARI flood event. For the proposed road the centreline level is lifted to RL 33.1 m and the flood elevation is 31.22 m which increases the freeboard to +1.88 m. This is a positive effect.
- Coatesville Riverhead Highway south of Moontide Road (Chainage 700, Points 15 and 16 in Figure 11-1) the road currently overtops during the 100 year ARI flood event. For the proposed road the centreline level is lifted to RL 32.1 m and the post-development flood level is RL 30.52 which increases the freeboard to +1.58 m.
- Coatesville Riverhead Highway north of Brigham Lane (Chainage 320, Points 17 and 18 in Figure 11-1) the road currently overtops during the 100 year ARI flood event. For the proposed road the centreline level is lifted to RL 31.5 m and modelling of the design case found the flood level would be RL 29.25 which increases the freeboard to +2.25 m.

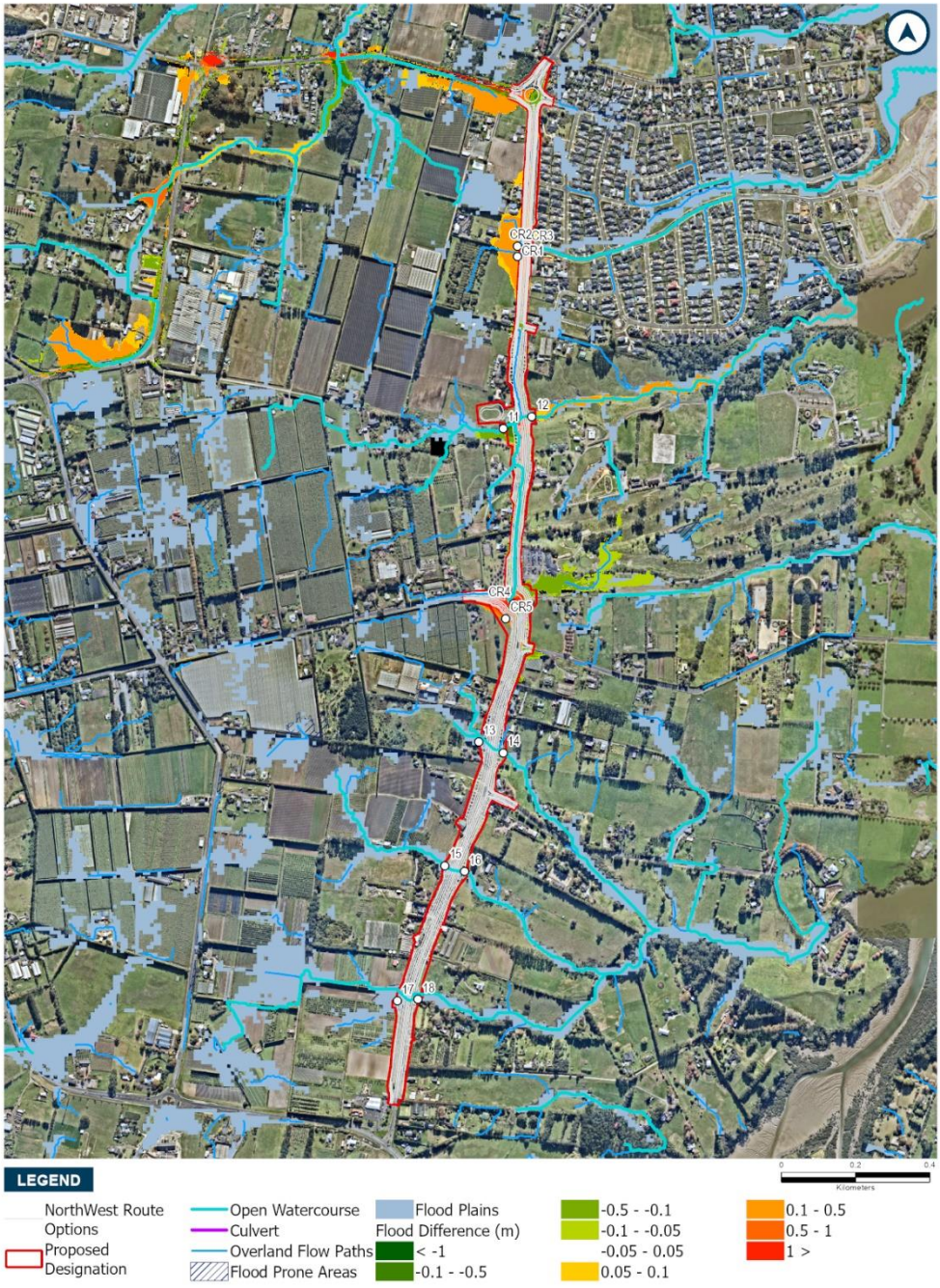

Figure 11-1: 100 year ARI flood difference map for Coatesville Riverhead Highway

11.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 7 above.

11.4.3 Recommended Measures to Minimise, 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 mitigation measures as set out in Section 7.1 apply.

11.4.4 Assessment of Operational Effects

11.4.4.1 Coatesville Riverhead Highway at Riverhead Point Drive

The assessment found flood plain and flood prone areas are evident next to the road and the flood plain overtops the existing road. The existing drainage consist of earth channels on the western side of the road that drains into a pipe network and discharges to an open channel further east of the corridor. Water ponding on the western side may be due to the pipes being undersized.

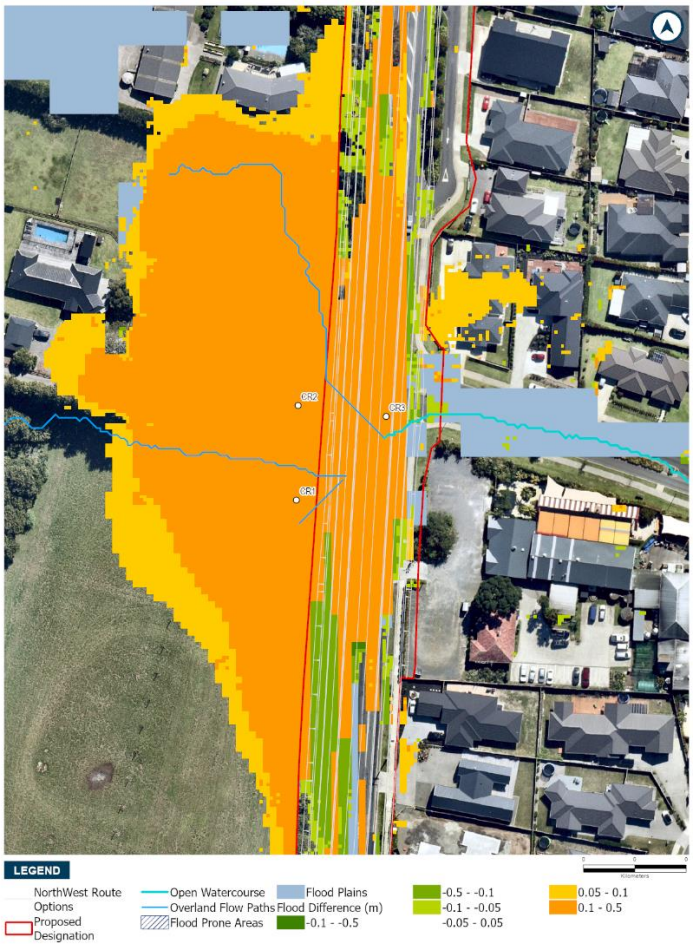

Figure 11-2: 100 year ARI flood difference map for Coatesville Riverhead Highway at Riverhead Point Drive

The 100 year pre-development flood level at point CR3, as shown in Figure 11-2, is RL 31.87 m under the post-development scenario the flood level is 32.06 with a flood level difference of 0.20 m. The existing road centreline level is RL 31.78 m and currently overtops during a 100 year ARI flood event. Under the current design the centreline of the proposed road is lifted to RL 31.88 m, however the road will still overtop.

Properties at 1170 and 1186 Coatesville-Riverhead Highway (points CR1 and CR2 in Figure 11-2) are within the FUZ and also within existing flood plain and flood prone areas. The existing flood prone area on these properties will be filled by the proposed road which will potentially increase flood levels west of the road or create new flood prone areas nearby unless added capacity is provided to reduce this impact. Mitigation is required and could include a new channel with inlet structure west of corridor and upgrade to the pipe network. This is possible within the current designation boundary and a final solution can be addressed at a future stage of design.

11.4.4.2 Coatesville Riverhead Highway at Old Railway Drive

There is a positive effect at point CR4 (Figure 11-3) as the vertical alignment of the road has increased to RL 33.25 m. However, the road may still overtop during the 100 year ARI event with flooding approximately 0.01m. This flood effect would have a negligible flood depth. Mitigation for this effect could be to raise the alignment to increase freeboard. This is possible within the current designation boundary and a final solution can be addressed at a future stage of design.

The increased vertical alignment has also created an area of ponding at point CR5. In addition to the area of increased flood difference the road overtops at this location. Flood effects could be alleviated by providing drainage infrastructure such as a channel alongside the proposed road with a culvert underneath the road corridor to convey water to the east to discharge. This is possible within the current designation boundary and a final solution can be addressed at a future stage of design.

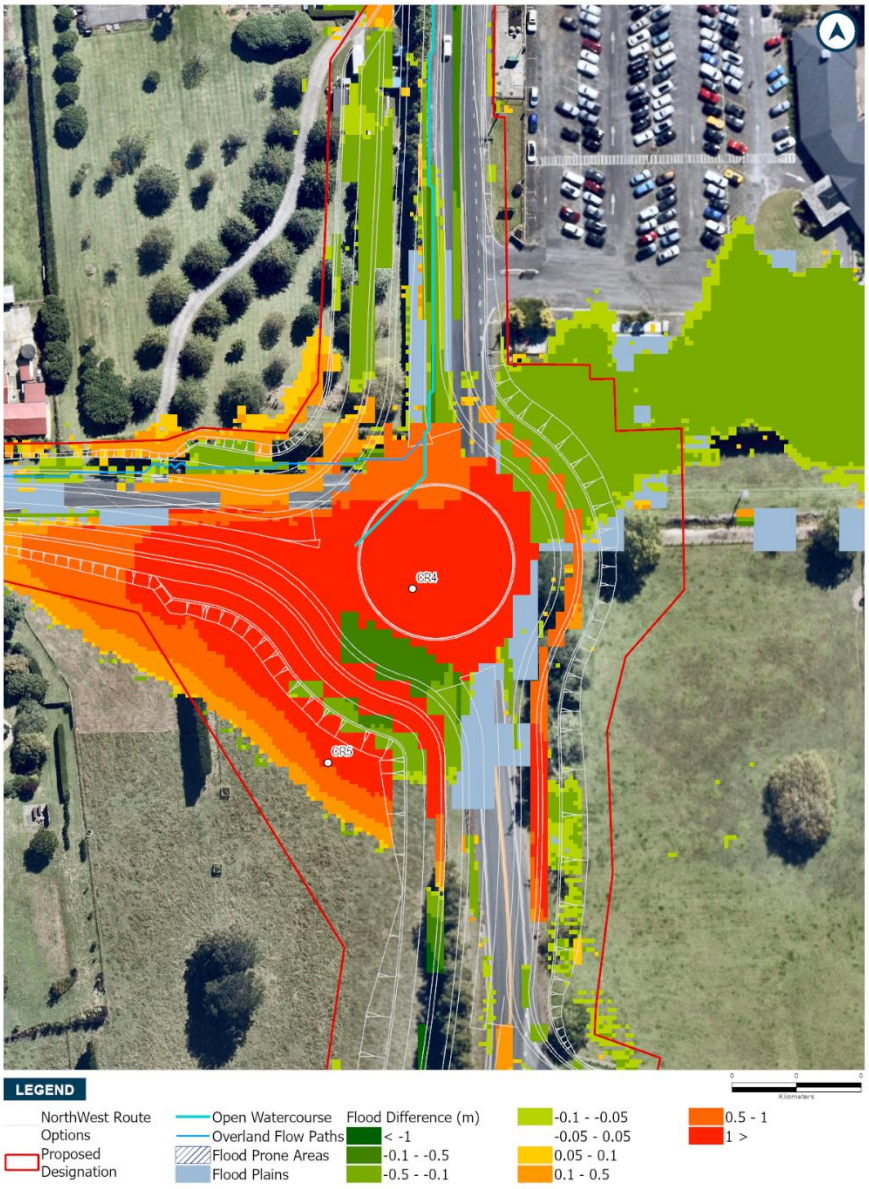

Figure 11-3: 100 year ARI flood difference map for Coatesville Riverhead Highway at Old Railway Drive

11.4.4.3 Coatesville Riverhead Highway south of Short Road (Chainage 1940)

While positive effects at Coatesville Riverhead Highway south of Short Road (Chainage 1940) are reported due to increased freeboard there is a minor effect downstream as a result of the culvert modelled being too large (points 11 and 12 Figure 11-4). The culvert size could be refined during detailed design to achieve flood neutrality. This mitigation can be achieved within the current designation boundary and a final solution can be addressed at a future stage of design.

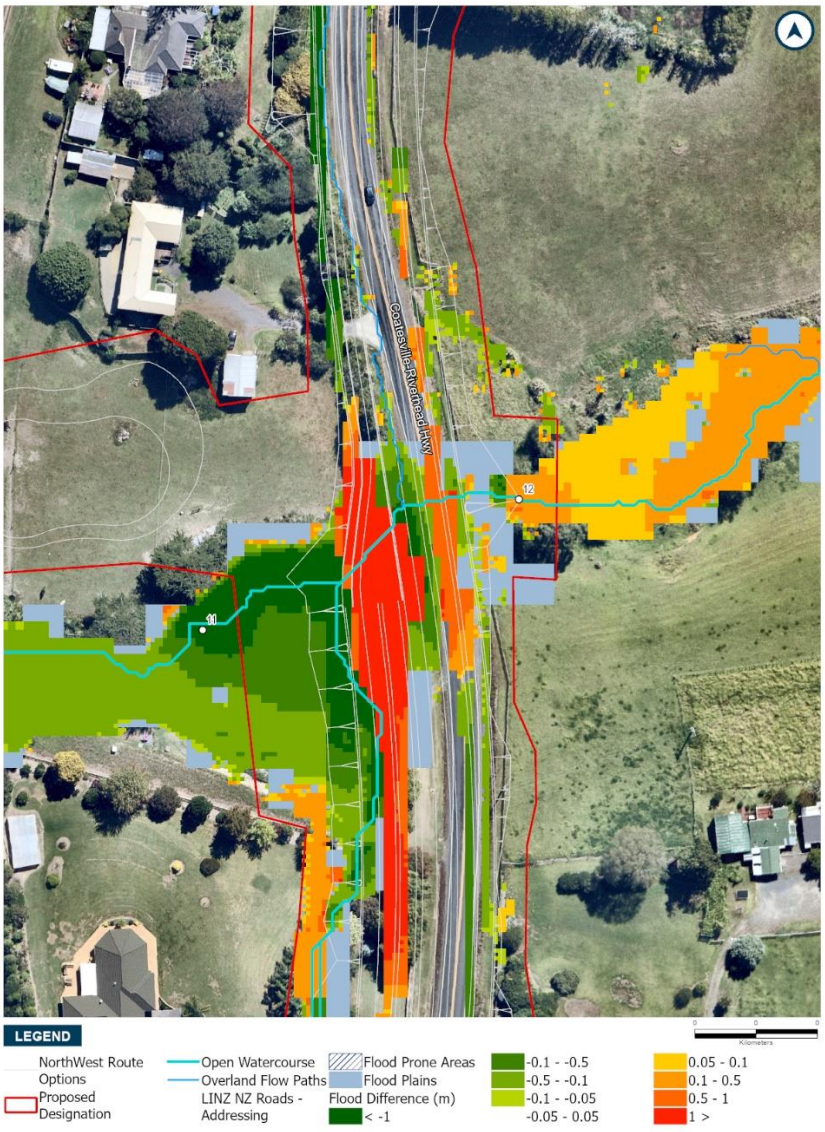

Figure 11-4: 100 year ARI flood difference map for Coatesville Riverhead Highway south of Short Road

11.4.4.4 Coatesville Riverhead Highway north of Moontide Road (Chainage 1040)

Coatesville Riverhead Highway north of Moontide Road (Chainage 1040) has a positive effect reported due to increased freeboard. At this location an undersized culvert is creating ponding upstream (points 13 and 14 Figure 11-5). Resizing of the culvert during detailed design should seek to achieve flood neutrality. This mitigation can be achieved within the current designation boundary.

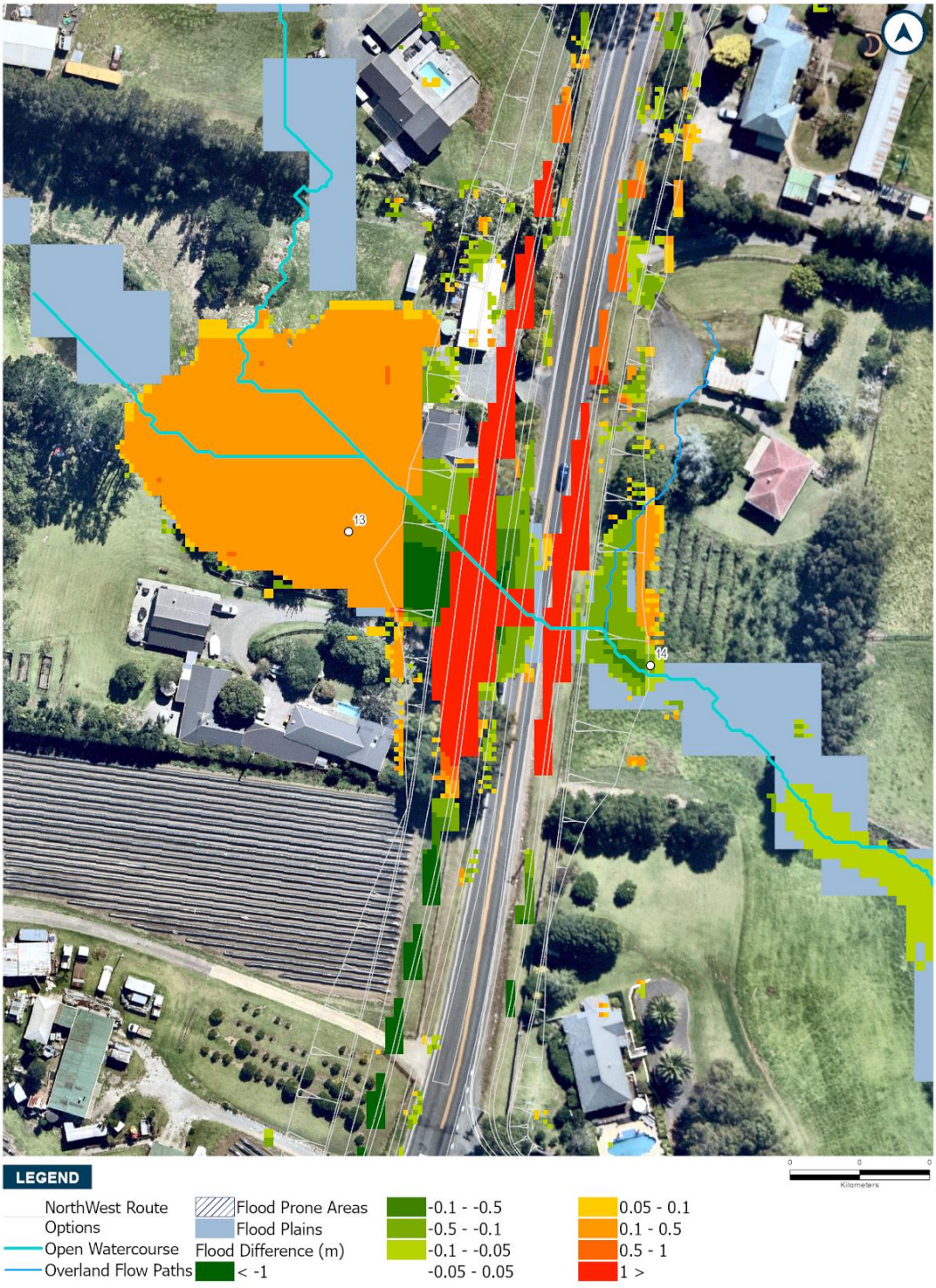

Figure 11-5: 100 year ARI flood difference map for Coatesville Riverhead Highway north of Moontide Road

11.4.5 Recommended Measures to Minimise, 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:

- Increasing culvert size south of Short Road (Chainage 1940) so that the upstream and downstream flood levels do not increase by more than 0.05 m
- Decreasing culvert size north of Moontide Road (Chainage 1040) so that the upstream and downstream flood levels do not increase by more than 0.05 m
- Include a new 5 m wide channel/drain west of the corridor between Chainage 2260-2460 with an inlet structure to connect to an upgraded underground pipe network to allow more flow through to discharge to the open channel east near the intersection of Riverhead Point Drive
- Raise the road alignment and provide additional drainage capacity at Coatesville-Riverhead Highway near Old Railway Drive to reduce ponding

While some of the potential operational effects were assessed as moderate these are likely to be significantly reduced with the mitigation measures above. Further assessment at the detailed design stage can be used to confirm the potential effects following mitigation.

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.

11.5 Conclusions

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

The corridor is currently under the 100 year ARI flood plain hence the proposed road with a lifted vertical alignment will increase freeboard and a reduce the potential flood risk resulting in a number of positive effects. The assessment of operational effects found minor to moderate flood effects.

Effects could be mitigated by providing new channels or drains next to corridor to increase attenuation and lower the peak flow and diverting flows to discharge to new inlet/pipe. Mitigation will be confirmed at detailed design stage.

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

12 Sensitivity Analysis

The sensitivity analysis at the locations where a flood risk has been identified are shown in Table 12-1 and Table 12-2. For this Project the road corridors are generally at a higher elevation and follow existing roads. The sensitivity analysis found that there was no change to the identified flood risk at these locations under a more severe climate change scenario (3.8 degree temperature change).

12.1.1 NoR RE1: Don Buck Road FTN Upgrade

This corridor is located on a ridgeline and crosses no major overland flow paths or streams and is outside any floodplain or flood prone areas therefore no operational effects are anticipated.

12.1.2 NoR RE2: Fred Taylor Drive FTN Upgrade

There was a flood level change of up to +0.04 m at Fred Taylor Drive (point FT1) however there was no change to the potential flood effect (Table 12-1). There was an increased flood effect at point FT3 of +0.02m this resulted in an increase in flood effect from minor to moderate (Table 12-1). No further mitigation is proposed beyond that already recommended. It is expected that revised modelling at the detail design stage will consider any additional climate change requirements.

Table 12-1: Consideration of flooding at key locations identified NoR RE2: Fred Taylor Drive

Point on flood difference map	2.1 degree temperature change		3.8 degree temperature change		Flood depth change (m)
	Water Level (m)	Potential Effect	Water Level (m)	Potential Effect	
FT1	42.46 m	Minor	42.49 m	Moderate	+0.02 m
FT2	43.21 m	Moderate	43.25 m	Moderate	+0.04 m
FT3	52.78 m	Minor	52.81 m	Moderate	+0.02 m

12.1.3 NoR R1: Coatesville-Riverhead Highway Upgrade

There was a flood level change of +0.14 m upstream and +0.16 m downstream of Coatesville Riverhead Highway south of Short Road (Chainage 1940) for the upgrade of Coatesville-Riverhead Highway (NoR R1) which resulted in a potential increase in flooding at this location. For other locations along Coatesville-Riverhead Highway, even with increased flood levels due to climate change there was no change to the effect.

For properties assessed at most locations there was no change to flood levels or flood risk. No further mitigation is proposed beyond that already recommended. It is expected that revised modelling at the detail design stage will consider the appropriate RCP, or any additional climate change requirements.

Table 12-2: Flood levels at key crossings NoR R1: Coatesville-Riverhead Highway

Chainage	Proposed cross drainage	2.1 degree temperature change	3.8 degree temperature change	Flood level change	Change in potential effect without mitigation
		100 Year flood level (RL) pre-development	100 Year flood level (RL) pre-development		
Coatesville Riverhead Highway south of Short Road (Chainage 1940)	(x2) 3000 mm x 1000 mm box culverts Design road CL level RL 31.5 m	29.25 m upstream 28.40 m downstream	29.34 m upstream 28.45 m downstream	+0.09 m upstream +0.04 m downstream	Upstream no change – positive effect Downstream no change – positive effect
Coatesville Riverhead Highway north of Moontide Road (Chainage 1040)	(x2) 2500 mm x 1000 mm box culverts Design road CL level RL 32.1 m	30.52 m upstream 28.20 m downstream	30.70 m upstream 28.23 m downstream	+0.18 m upstream +0.03 m downstream	Upstream reduction in freeboard – negligible effect Downstream no change – positive effect
Coatesville Riverhead Highway south of Moontide Road (Chainage 700)	(x2) 2000 mm x 1000 mm box culverts Design road CL level RL 33.1 m	31.22 m upstream 28.33 m downstream	31.30 m upstream 28.37 m downstream	+0.07 m upstream +0.04 m downstream	Upstream no change – positive effect Downstream no change – positive effect
Coatesville Riverhead Highway north of Brigham Lane (Chainage 320)	(x2) 3000 mm x 1000 mm box culverts Design road CL level RL 21.49 m	19.33 m upstream 18.07 m downstream	19.47 m upstream 18.23 m downstream	+0.14 m upstream +0.16 m downstream	Upstream no change – positive effect Downstream increased flood level – Minor

Table 12-3: Consideration of flooding at key locations identified NoR R1: Coatesville-Riverhead Highway

Point on flood difference map	2.1 degree temperature change		3.8 degree temperature change		Flood depth change (m)
	Water Level (m)	Potential Effect	Water Level (m)	Potential Effect	
1170 Coatesville-Riverhead Highway (Point CR1)	32.06 m	Minor	32.08 m	Minor	+0.02 m
1186 Coatesville-Riverhead Highway (Point CR2)	32.06 m	Minor	32.08 m	Minor	+0.02 m
Coatesville-Riverhead Highway at Riverhead Point Drive (Point CR3)	32.04 m	Minor	32.05 m	Minor	+0.02 m
Coatesville-Riverhead Highway at Old Railway Drive (Point CR4)	33.26 m	Positive	33.26 m	Positive	No change
Coatesville-Riverhead Highway at Old Railway Drive (Point CR5)	33.31 m	Moderate	33.32 m	Moderate	+0.02 m

13 Conclusion

The assessment reviewed the flood risk for:

- NoR RE1 Don Buck Road FTN Upgrade
- NoR RE2 Fred Taylor Drive (alteration to existing designation 1433)
- NoR R1 Coatesville-Riverhead Highway Upgrade

NoR RE1 (Don Buck Road FTN Upgrade) was note modelled as this corridor is on a ridgeline and the area has already been developed. There is no change expected as a result of the Project.

NoR RE2 (Fred Taylor Drive) and NoR R1 (Coatesville-Riverhead Highway Upgrade) were assessed using the predicted flood depth based on the results of modelling of the existing terrain assuming 100 year with climate change rainfall and future fully developed catchments. Locations where flooding is predicted were identified and the flood effects ascertained.

The assessment found that there was unlikely to be an increased risk from flood effects during construction and flood effects will be managed as set out in Section 7.1.

The assessment identified during operations likely positive effects based on the vertical elevation of the reference design which would increase freeboard at several locations including along the Coatesville-Riverhead Highway.

The assessment found that during operation there were areas of minor and moderate flood effects from flooding in both NoR RE2 (Fred Taylor Drive) and NoR R1 (Coatesville-Riverhead Highway Upgrade). The assessment has recommended mitigation measures which could be implemented to address any flood effects, however, final measures will be identified at detailed design stage. There is sufficient area for mitigation measures to be implemented within the proposed designation boundary.

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. Additional modelling of the final design at a detailed design stage will be used to confirm that flood effects are minimised, remedied or mitigated as appropriate.

The sensitivity analysis for the potential increased rainfall due to climate change found there was no change to the identified flood risk at key locations under a more severe climate change scenario (3.8 degree temperature change).

14 References

Auckland Council (Nov 2011) Auckland Council Stormwater Modelling Specification

Auckland Council GeoMaps (accessed 2021)

Te Tupu Ngātahi flood models, as follows:

Available Models	**North West Redhills Riverhead Package projects within the catchment models**
Whenuapai Rapid Flood Hazard Assessment	Fred Taylor Drive FTN Upgrade (NoR RE2)
Redhills Rapid Flood Hazard Assessment	Fred Taylor Drive FTN Upgrade (NoR RE2)
Riverhead Rapid Flood Hazard Assessment	Coatesville-Riverhead Highway (NoR R1)

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 RE2: Fred Taylor Drive FTN Upgrade

Table 14-1: Properties potentially at risk of flooding along Fred Taylor Drive FTN Upgrade

Point on difference map	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100 Year flood depth and flood level (RL) pre-development	100 Year flood depth and flood level (RL) post-development	Level difference for 100 year flood	Potential effect without mitigation
FT1 (Figure 10-1)	166 Fred Taylor Drive, Whenuapai	Building/ house/ driveway, FUZ, ground level RL 42.28 m	42.33 m	42.46 m	+0.13 m	Minor effect
FT2 (Figure 10-1)	160 Fred Taylor Drive, Whenuapai	Open area, FUZ, ground level RL 42.52 m	42.97 m	43.21 m	+0.24 m	Minor effect
FT3 (Figure 10-1)	112 Fred Taylor Drive, Whenuapai	Building/ house/ driveway, FUZ, ground level RL 52.62 m	52.66 m	52.78 m	+0.12 m	Minor effect

1.2 NoR R1: Coatesville-Riverhead Highway Upgrade

Table 14-2: Coatesville-Riverhead Highway Upgrade existing flood levels at key crossings

Point on difference map	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100 Year flood depth and flood level (RL) pre-development	100 Year flood depth and flood level (RL) post-development	Level difference for 100 year flood	Potential effect without mitigation
Coatesville Riverhead Highway south of Moontide Road (Chainage 700, points 15 and 16 Figure 11-1)	Unknown Existing road CL level RL 30.27 m	(x2) 2500 mm x 1000 mm box culverts Design road CL level RL 32.1 m	30.58 m upstream, 28.13 m downstream	30.52 m upstream, 28.20 m downstream	-0.06 m upstream, +0.07 m downstream	Positive effect upstream, minor effect downstream
Coatesville Riverhead Highway north of Brigham Lane (Chainage 320, points 17 and 18 in Figure 11-1)	Unknown Existing road CL level RL 30.6 m	(x2) 3000 mm x 1000 mm box culverts Design road CL level RL 31.5 m	30.90 m upstream, 28.51 m downstream	29.25 m upstream, 28.40 m downstream	-1.65 m upstream, -0.11 m downstream	Positive effect
Point CR1 (Figure 11-2)	1186 Coatesville-Riverhead Highway, Riverhead	Open area, FUZ, ground level RL 31.71 m	31.86 m	32.06 m	+0.20 m	Minor effect
Point CR2 (Figure 11-2)	1170 Coatesville-Riverhead Highway, Riverhead	Open area, FUZ, ground level RL 31.69 m	31.87 m	32.06 m	+0.19 m	Minor effect
Point CR3 (Figure 11-2)	Coatesville-Riverhead Highway, near Riverhead Point Drive Road corridor, top of road RL 31.77 m	Road corridor, top of road RL 31.77 m	31.84 m	32.04 m	+0.20 m	Minor effect

Point on difference map	Existing Cross Drainage / Property address	Modelled Cross Drainage / Affected area	100 Year flood depth and flood level (RL) pre-development	100 Year flood depth and flood level (RL) post-development	Level difference for 100 year flood	Potential effect without mitigation
Point CR4 (Figure 11-3)	Coatesville-Riverhead Highway, near Old Railway Road Road corridor, ground level RL 32.27 m	Road corridor, top of road RL 33.25 m	32.10 m	33.26 m	+1.16 m	Negligible effect as new road level predicted to have +0.01m flood depth
Point CR5 (Figure 11-3)	Coatesville-Riverhead Highway, near Old Railway Road Road corridor, ground level RL 31.27 m	Road corridor, top of road RL 32.27 m	32.19 m	33.31 m	+1.05 m	Moderate Effect
Coatesville Riverhead Highway south of Short Road (Chainage 1940, points 11 and 12 Figure 11-4)	1200 mm diameter pipe Design road CL level RL 20.24 m	(x2) 3000 mm x 1000 mm box culverts Design road CL level RL 21.49 m	20.42 m upstream, 17.87 m downstream	19.33 m upstream, 18.07 m downstream	-1.09 m upstream, +0.20 m downstream	Positive effect upstream and minor effect downstream
Coatesville Riverhead Highway north of Moontide Road (Chainage 1040, points 13 and 14 Figure 11-5)	Unknown Design road CL level RL 30.6 m	(x2) 2000 mm x 1000 mm box culverts Design road CL level RL 33.1 m	30.89 m upstream, 28.45 m downstream	31.21 m upstream, 28.33 m downstream	0.32 m upstream, -0.12 m downstream	Minor effect upstream and positive effect downstream