TE TUPU NGĀTAHI
SUPPORTING GROWTH

VOLUME 4

Airport to Botany - Assessment of Flooding Effects

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Version 1

WAKA KOTAHI
NZ TRANSPORT AGENCY

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Glossary of defined terms and acronyms

Acronym/Term	Description
AEE	Assessment of Effects on the Environment report
ARI	Average Recurrence Interval
AUP:OP	Auckland Unitary Plan: Operative in Part
BRT	Bus Rapid Transit
CEMP	Construction Environmental Management Plan
CVA	Cultural Values Assessments
MPD	Maximum Probable Development
N/A	Not Applicable
NIMT	North Island Main Trunk railway track
NoR	Notice of Requirement
NoR 1	Notice of Requirement 1: Airport to Botany Bus Rapid Transit (Botany Town Centre to Rongomai Park)
NoR 2	Notice of Requirement 2: Airport to Botany Bus Rapid Transit (Rongomai Park to Puhinui Station, in the vicinity of Plunket Avenue)
NoR 3	Notice of Requirement 3: Airport to Botany Bus Rapid Transit (Puhinui Station, in the vicinity of Plunket Avenue to SH20/20B Interchange)
NoR 4a	Notice of Requirement 4a: Airport to Botany Bus Rapid Transit (SH20/20B Interchange to Orrs Road)
NoR 4b	Notice of Requirement 4b: Alteration to NZ Transport Agency Designation 6717 – State Highway 20B
NPS:UD	National Policy Statement on Urban Development
Programme partners	Te Ākitai Waiohua, Auckland Airport, Auckland Transport and Waka Kotahi
RCA	Road Controlling Authority
RLTP	Auckland Regional Land Transport Plan
RMA	Resource Management Act 1991
RP	Regional Plan
RPS	Regional Policy Statement
SEA	Significant Ecological Area
SH1	State Highway 1
SH20	State Highway 20
SH20B	State Highway 20B

SMAF	Stormwater Management Area Control – Flow
Te Tupu Ngātahi	Te Tupu Ngātahi Supporting Growth
Waka Kotahi	Waka Kotahi NZ Transport Agency

Executive summary

This report provides an assessment of flood hazard risks associated with the construction, operation and maintenance of the Airport to Botany Bus Rapid Transit project (the **Project**).

Flooding is a natural hazard and has therefore been considered as part of the Notices of Requirement (**NoRs**) for the Project. The works required for the Project have the potential to lead to flooding effects and an assessment is provided to demonstrate that these effects can be appropriately avoided, remedied or mitigated in the future, closer to the construction of the Project. 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; and
- The level of flooding to roads, cycleways and footpaths;

The assessment of flooding effects for the Project has involved the following steps:

- Desktop assessment to identify potential flooding location;
- Modelling of the pre-development terrain with Maximum Probable Development (**MPD**) and future 100 year Average Recurrence Interval (**ARI**) plus climate change rainfall;
- Modelling of two climate scenarios, one allowing for 2.1 degrees of temperature increase and one for 3.8 degrees of temperature increase. The higher climate change scenario has been used to undertake a sensitivity analysis; and
- Inspection and review of flood depths at key locations such as crossings and where there is more vulnerable development e.g. dwellings.

While stormwater effects apart from flooding are not assessed (as these are part of future consenting processes), provision is made for the future mitigation of potential stormwater effects (stormwater quality and retention/detention) by identifying the space required for stormwater management devices (for example drainage channels and ponds) and incorporating sufficient land for that purpose into the proposed designation boundaries. The assessment considers that flooding effects will be subject to further assessment at a future detailed design stage.

The Project will lead to an increase to impervious area within the future corridor between 5% and 15% adjacent to urban areas. However, as a contribution to catchment wide flooding problems, the Project is expected to cause limited flooding effects. Design refinements or matters to be addressed at detailed design have been identified and there is sufficient space within the proposed designations for stormwater and flood mitigation. There are a number of existing flood areas identified along the route – these have been assessed to identify the level of hazard and potential effects outside the corridor. It will be important to make sure that the vertical alignment of the corridor crest does not change at these locations.

Summary of assessment of effects and recommendations

A flood risk rating was determined using flood depth from the model outputs compared to the proposed road levels and existing ground levels in the terrain model to identify where there was an existing flood risk (and hence where the Project works could exacerbate flooding). The flood risk was assessed according to the criteria set out in Table 4.

The outcomes of the flood assessment are set out in the table below.

Table 1: Summary of flooding assessment

NoR	Location	Flood Risk Rating	Recommendation
NoR 1	Te Irirangi Drive near Bishop Dunn Place	Negligible	N/A
	Te Irirangi Drive south of Smales Road	High	• Lower the intersection to allow flood water to move from trapped low point • Investigate additional pipe capacity and inlets • No flood flow attenuation for increased impervious area as the existing road corridor is in the lower half of the catchment
	Te Irirangi Drive north of Smales Road	Moderate	• Provide additional or upsized piped drainage and/or greater inlet capacity • No flood flow attenuation for increased impervious area as the existing road corridor is in the lower half of the catchment
NoR 2	Te Irirangi Drive near Diorella Drive / Boundary Road	Low to negligible	• No flood flow attenuation for increased impervious area for sub-catchment to the existing Rongomai attenuation pond • Flood flow attenuation for increased impervious areas within the proposed raingardens (if required) for sub-catchment to Ōtara Creek
	Lambie Drive / Cavendish Drive	High	• Keep the current vertical alignment • Flood flow attenuation for increased impervious areas

			within proposed linear treatment
	Davies Avenue / Ronwood Avenue	Moderate - High	• Reduce the level of Davies Avenue to allow overland flow to discharge into Hayman Park • Provide additional pipe capacity or diversion drains parallel to the road • Flood flow attenuation for increased impervious areas within the proposed wetland at Hayman Park
	Puhinui Road near Cavendish Drive	High	• Keep the current vertical alignment • Flood flow attenuation for increased impervious areas within the proposed designation boundary (if required)
NoR 3	Puhinui Road near Noel Burnside Road	High	• Keep the current vertical alignment • Flood flow attenuation for increased impervious areas within the proposed designation boundary (if required)
NoRs 4a and 4b	Puhinui Road between Vision Place and SH20/20B Interchange	Moderate	• No flood flow attenuation for increased impervious area • Increase culvert capacity if required

1 Introduction

1.1 Purpose and scope of this Report

This assessment of flood hazard effects has been prepared to inform the Assessment of Effects on the Environment (**AEE**) for five NoRs being sought by Waka Kotahi NZ Transport Agency (**Waka Kotahi**) and Auckland Transport (**AT**) for the Project under the Resource Management Act 1991 (**RMA**). Specifically, this Report considers the actual and potential effects associated with the construction and operation of the Project on the existing and likely future environment as it relates to flood hazard effects and recommends measures that may be implemented to avoid, remedy and/or mitigate these effects.

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 stormwater quantity effects (such as flooding, erosion and changes to hydrology – which may cause effects onstream habitat, baseflow and sediment movement in streams), stormwater discharge 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 section 13, 14 and 15 of the RMA and are administered through regional consents by Auckland Council.

A designation is a land use or district planning mechanism. Accordingly, when assessing the actual or potential stormwater effects on the environment of allowing the requirement in terms of section 171 of the RMA, the assessment of effects has been limited to flood hazard matters being the specific matters that would trigger a District Plan consent requirement under the Auckland Unitary Plan (Operative in Part) (**AUP:OP**). Where Regional Plan consenting requirements are triggered, these will not be authorised by the designation, and will require further regional consents to be obtained prior to construction of the Project.

In presenting information on flood hazard effects, it is therefore acknowledged that there will be a subsequent process for seeking regional council consents. The NoRs also acknowledge that the works required for the Project could lead to risks associated with flooding as a natural hazard and provide an assessment of effects to demonstrate that these risks can be appropriately managed in the future.

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

- Increasing flood levels on adjoining property; and
- Increasing the flood hazard.

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 within each NoR, and the typical construction methodology 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 flood hazard effects. As such, they are not repeated here. Where a description of an activity is necessary to understand the potential effects, it has been included in this Report for clarity.

1.2 Report structure

In order to provide a clear assessment of each NoR, this Report follows the structure set out in the AEE. That is, each notice has been separated out into its own section, and each section contains an assessment of the actual and potential effects for the specific NoR. Where appropriate, measures to avoid, remedy or mitigate effects are recommended.

Each section is arranged in geographical order, starting from the northernmost point of the proposed NoR, to the southernmost point. Table 2 below describes the extent of each section, and where the description of effects can be found in this Report.

Table 2: Report structure

Sections	Section number
Description of the Project	2
Overview of the methodology used to undertake the assessment and identification of the assessment criteria and any relevant standards or guidelines	3
Assessment of general flooding and stormwater matters for all Airport to Botany Bus Rapid Transit NoRs	4
Assessment of specific flooding and stormwater matters for Airport to Botany Bus Rapid Transit NoR 1	5
Assessment of specific flooding and stormwater matters for Airport to Botany Bus Rapid Transit NoR 2	6
Assessment of specific flooding and stormwater matters for Airport to Botany Bus Rapid Transit NoR 3	7
Assessment of specific flooding and stormwater matters for Airport to Botany Bus Rapid Transit NoR 4a and 4b	8
Overall conclusion of the level of potential adverse flood effects of the Airport to Botany Bus Rapid Transit Project	10

2 Project description

The overall Project is proposed to be an 18km fast, high capacity, reliable, and frequent Bus Rapid Transit (**BRT**) connection with twelve stations. It is part of Auckland's wider Rapid Transit Network (**RTN**) connecting Auckland Airport and its employment areas with major urban centres including Manukau and Botany.

As set out in the AEE, this Report specifically relates to a portion of the broader Project (approximately 14.9km) which extends from the Botany Town Centre in the vicinity of Leixlep Lane to Orrs Road in the Puhinui peninsula, off SH20B. The Project primarily involves the upgrade and widening of existing transport corridors to provide for a separated bus rapid transit corridor and high-quality walking and cycling facilities.

Nine BRT stations are proposed as part of the Project. These stations will facilitate off-board ticketing and level boarding and are situated in the following locations:

- Smales Road;
- Accent Drive;
- Ormiston Road – Botany Junction Shopping Centre;
- Dawson Road;
- Diorella Drive;
- Ronwood Avenue (Manukau Central);
- Manukau Station;
- Puhinui Road/Lambie Drive; and
- Puhinui Station.

As part of the Project, two new structures are proposed:

- A BRT bridge crossing the North Island Main Trunk (NIMT) and connecting to the concourse level of the Puhinui Station; and
- A southbound ramp from SH20B to SH20.

Upgrades to existing structures are proposed at the:

- Bridge over Otara Creek (NoR 1);
- Bridge over SH1 (NoR 2);
- Bridge over NIMT (NoR 3); and
- Bridge over Waokauri Creek (NoR 4a).

Figure 1: Overview of Project and NoR extents

Table 3: Overview of NoRs

Notice of Requirement	Description	Requiring Authority
NoR 1	Bus Rapid Transit corridor and high quality walking and cycling facilities from Botany Town Centre to Rongomai Park	Auckland Transport
NoR 2	Bus Rapid Transit corridor and high quality walking and cycling facilities from Rongomai Park to Puhinui Interchange, in the vicinity of Plunket Avenue	Auckland Transport
NoR 3	Bus Rapid Transit corridor and high quality walking and cycling facilities from Puhinui Interchange, in the vicinity of Plunket Avenue to SH20/SH20B Interchange	Auckland Transport
NoR 4a	Bus Rapid Transit corridor and high quality walking and cycling facilities from SH20B/20 Interchange to Orrs Road	Auckland Transport
NoR 4b	Alteration to designation 6717 to provide for the widening of SH20B, including a southbound on-ramp onto SH20, high quality walking and cycling facilities and enable a Bus Rapid Transit corridor	NZ Transport Agency

3 Assessment methodology

3.1 Preparation for this Report

Several resources were used to support the assessment. These included site visits, technical specialist inputs, previous reports developed for the business case and the stormwater discharge consent application for SH20B, 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 flood models for Pūkaki Creek, Puhinui Creek, Ōtara Creek (including Flat Bush) and Pakuranga Creek catchments were used to assess the flood water levels and extents of the flooding on existing (pre-development) terrain.

3.2 Summary

The assessment of flooding effects for the Project has involved the following steps:

- Desktop assessment to identify potential flooding locations, namely:
  - Existing buildings appear to be near/within the existing flood plains; and
  - Where the Project involves work near stream crossings and major overland flow paths.
- Flood modelling of the pre-development terrain:
  - Flood modelling of the existing terrain using MPD development with 100 year ARI plus climate change rainfall (2.1 and 3.8 degree increase); and
  - Model results were used to identify flood water levels ≥ 0.05m for the future 100 year flood event.
- Inspection of the flood extent 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; and
  - 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 climate change on the results.

3.3 Outcomes based approach

The stormwater and flooding considerations are based on a concept design and proposed designation boundary which includes sufficient space to respond to the future environment. The effects assessment is based on the Project being able to meet the outcomes set out below and provide any required mitigation within the designation boundary.

The Project does not propose substantial changes to the vertical alignment of existing roads within the urban areas. Therefore, the Project geometry is expected to cause limited additional flooding effects, such as loss of flood plain storage or raising the overtopping level. Notwithstanding this, there are a number of locations where there is existing flood hazard. As such, future detailed design for the Project

will need to assess and manage potential flooding effects. In some areas, the corridor passes through existing flood plains and detailed design geometry will need to match the existing levels so as to not exacerbate effects.

There will also be some increase in impervious area within the urban parts of the Project corridor – in the order of 10%. As the retention and detention volumes will be sized for the impervious area of the whole Project corridor and increases in runoff relate to the change in impervious area, the storage will reduce the peak flow increases. The changes in impervious areas are small in the context of the overall catchments and are not expected to cause considerable effects. If future detailed modelling for the Project identifies the need for further flood attenuation, beyond what is currently provided for, the designation boundary provides sufficient space for this to be incorporated into proposed treatment devices or located adjacent to the corridor.

In any case, during the future detailed design stage of the Project, measures should be implemented 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); and
- No more than a 10% average increase of flood hazard (defined as flow depth times velocity) for the main access to authorised habitable dwellings.

Where the above outcomes can be achieved through alternative measures outside of the proposed designations 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 existing flood effects occur and may require mitigation. The designation boundary allows for treatment and retention/detention devices which include some storage. However, the final geometric design will be more important in not exacerbating existing flood effects.

Compliance with these flooding outcomes should 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 MPD and climate change) at the future resource consent stage of the Project.

3.4 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 work near the stream crossings / major overland flow paths; and
- 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:

- AUP:OP;
- Auckland Council GIS resources (Auckland GeoMaps);
- Design Drawings;
- Flood maps created by the SG modelling team;
- SGA Flood Resilience Technical Note;
- Indicative Construction Methodologies;
- NZTA Stormwater Specification P46;
- New Zealand Bridge Manual (SP/M/022) for freeboard allowance;
- Puhinui Catchment Management Plan;
- The Auckland Code of Practice for Land Development and Subdivision Chapter 4: Stormwater, Version 3.0, January 2022;
- Auckland Transport Hīkina te Wero: Environment Action Plan, December 2021; and
- Waka Kotahi Toitū Te Taiao Sustainability Action Plan, April 2020.

3.5 Flood modelling

3.5.1 Purpose

The purpose of the flood modelling is to identify the extent and scale of existing flooding effects. We have used this to consider how the proposed Project corridor may exacerbate existing flooding and potential methods to manage these effects.

3.5.2 Stormwater catchment overview

As set out in the figure below, the Project traverses four major stormwater catchments: Pakuranga Creek, Ōtara Creek/Flat Bush, Puhinui Creek and Pūkaki Waokauri Creek.

The Pakuranga Creek catchment covers approximately 2,918 ha, but the Project covers only a small area in the southern portion of this catchment. Runoff from the Pakuranga Creek catchment drains to the Pakuranga Creek before discharging to the Tāmaki River and further the Waitematā Harbour. The Pakuranga Creek catchment is highly developed. The downstream environment includes significant existing flood hazards.

The Ōtara Creek/Flat Bush catchment covers approximately 3,477 ha. Ōtara Creek catchment is heavily modified with both industrial and residential development. Runoff from the Ōtara Creek/Flat Bush catchment drains to open watercourses before discharging to the Tāmaki River via the Ōtara Creek. Stormwater runoff from the Project area to the north of Ormiston Road will discharge to the Flat Bush Dam before discharge to Ōtara Creek. The downstream environment includes significant existing flood hazards.

The Puhinui Creek Catchment covers approximately is 2,964 ha. The majority of the catchment is highly developed and includes a large area of commercial and industrial development. Large sections of both the upper and lower catchment are open space. The main channel of the Puhinui Stream flows north-west towards the Manukau Town Centre and then east to the coast near the Papakura Channel of the Manukau Harbour. Puhinui Creek Catchment discharges by means of two streams namely, Puhinui Creek and Homai Stream and into Manukau Harbour. The Puhinui Creek Catchment includes a

number of areas with high flood hazard including Lambie Drive and Cavendish Drive where works will be undertaken.

The Pūkaki Waokauri catchment is approximately 1,727 ha in size. Stormwater runoff from the Project within the Pūkaki Waokauri catchment discharges to the Waokauri Creek, which discharges to the Pūkaki Creek and then into Manukau Harbour. The Pukaki-Waokauri catchment that SH20B passes through has been identified in the Stormwater Management Area Control – Flow 1 (**SMAF 1**) area under the AUP:OP.

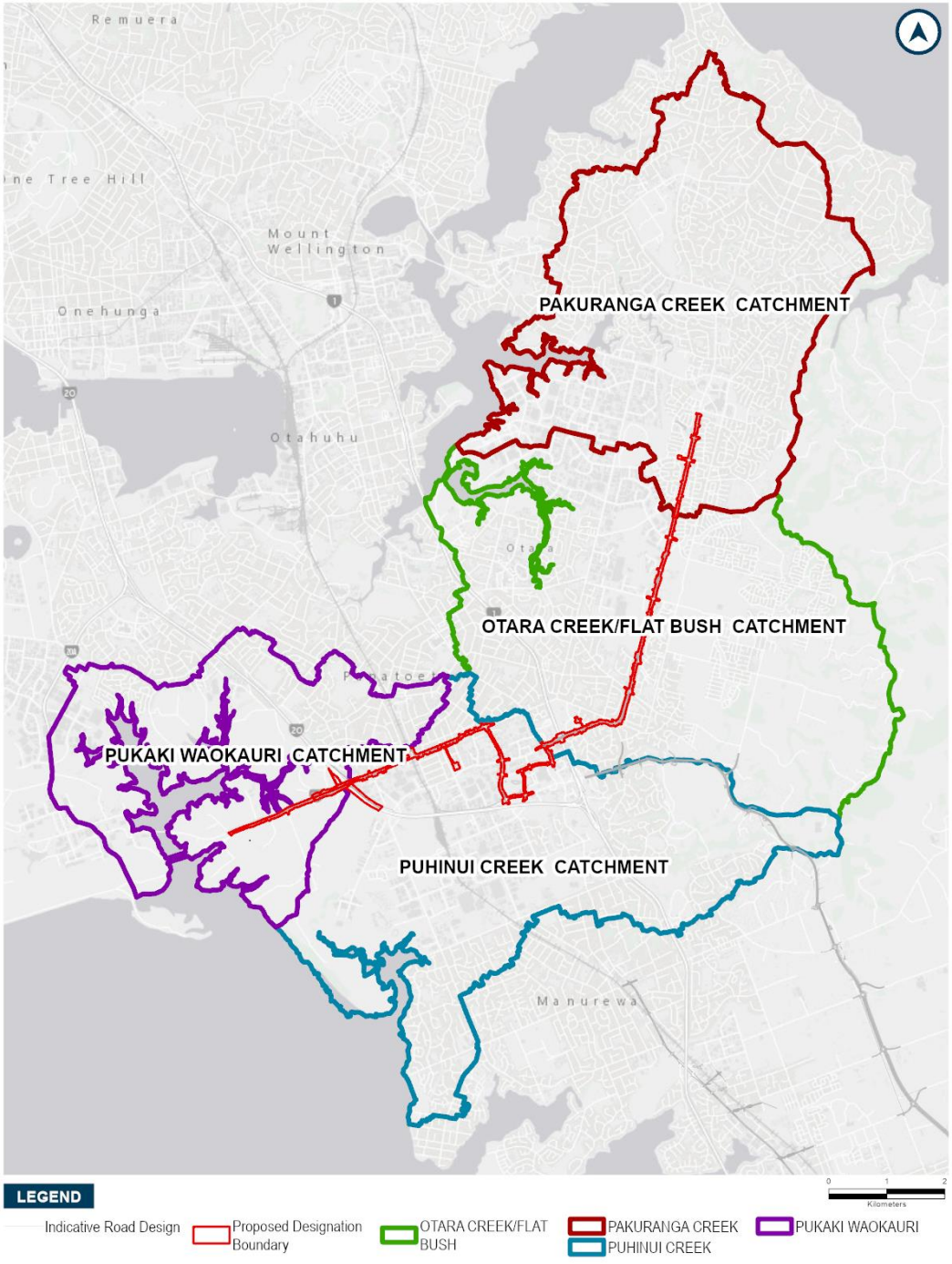


Figure 2: Stormwater catchments for the Project

3.5.3 Modelling parameters

Auckland Council have produced catchment models for Pūkaki Waokauri, Puhinui Creek, Flat Bush, Ōtara Creek and Pakuranga Creek which were adapted for this assessment (**the models**).

To assess the flooding effects of the Project on the receiving environment, the base case scenario was reviewed and areas with the potential for increase in flood risk were identified. To date, only the pre-development scenario has been modelled, this is based on:

- Future 100 year ARI rainfall event + climate change event with future land-use without the Project in place.

The proposed imperviousness for the 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 AUP:OP, the probable level of development arising from zone changes.

The models include the existing roads and existing culverts where the culverts are 600 mm or greater. In the models existing culverts < 600 mm diameter are considered to be fully blocked (according to the Auckland Council Code of Practice) although larger culverts are considered to be fully working.

The post-development flood models for the Project were not developed or assessed in this Report. It is anticipated that these models will be developed during detailed design when a final Project alignment is developed. Future modelling will be used to confirm that flood effects associated with the Project will be adequately mitigated.

3.5.4 Modelling outputs

The flood depth from the model outputs was compared to the proposed road levels and existing ground levels in the terrain model to identify where there was a potential flood risk. The existing ground level or road level was taken from the terrain model which is broadly based on 2016 LiDAR information. This was confirmed using contour information available from Auckland Council Geomaps.

The existing flood risk was assessed according to the criteria set out in Table 4. For those areas identified as having a potential risk of flooding effects, the key mitigation will be to maintain existing road crest levels.

Table 4: Flooding effects risk assessment criteria

Flood depth / land use	Negligible (flood depth < 0.05 m)	Low (flood depth 0.05 m to 0.15 m)	Moderate (flood depth 0.15 m to 0.5 m)	High (flood depth > 0.5m)
Less Vulnerable e.g. open space, agricultural land				
Moderately Vulnerable e.g. commercial and industrial, road corridors				
Highly Vulnerable e.g. dwellings, educational facilities				

Overall Flood Risk	Negligible	Low	Moderate	High

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. Surveyed floor levels of the existing habitable buildings are not available and should be reviewed in the future detailed design stage of the Project.

The required freeboard for bridges and culverts used to assess the suitability of the indicative design is set out in Table 5. Positive effects have been identified where the proposed vertical alignment of the road would increase freeboard to meet the allowance in Table 5.

Table 5: 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

3.5.5 Stormwater devices

As set out in the Section 1, this assessment is limited to flooding effects. Notwithstanding this, the concept design and proposed designation boundary provides for the future management of other stormwater effects (stormwater quantity and quality). The area required for stormwater devices within the proposed designation boundaries is based on a high-level indicative sizing of the device and area required for construction.

As set out in the AEE, a stormwater philosophy has been developed for the Project in partnership with Manawhenua. This sets out the stormwater management approach to inform future design and implementation. In summary, the approach identifies preferred treatment approaches along the Project corridor and includes linear treatment, use and/or enhancement of existing public stormwater treatment ponds, raingardens and new treatment devices.

The stormwater infrastructure has been conceptually designed in accordance with:

- Auckland Council's Stormwater Management Devices in the Auckland Region, Guideline Document 2017/001 (December 2017);
- Auckland Transport's Stormwater Guidelines (February 2014);
- The Waka Kotahi Stormwater Design Philosophy Statement (May 2010); and
- AUP:OP Stormwater Management Requirements.

In general, the approach has been to avoid locating stormwater devices in floodplains where possible. However, there are extensive flood plains covering and adjacent to the Project and this has not been

possible in a number of locations. Where applicable, this is discussed in the NoR specific sections to follow.

3.5.6 Limitations

NoRs 4a and 4b have downstream catchments which contain Future Urban Zoned land. The modelled scenarios use imperviousness assumptions associated with the future land use(s) shown in the Future Urban Land Supply Strategy.

Given the area of Future Urban Zoned land in NoRs 4a and 4b and the likely increase in density that is anticipated following the National Policy Statement on Urban Development (**NPS:UD**) along the rest of the NoRs, 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 detailed design phase of the Project to take account of catchment characteristics at that time and to confirm proposed mitigation.

Similarly, 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.

3.5.7 Sensitivity analysis

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given exposure[1]. In this instance the sensitivity of the proposed designations to increased rainfall as a result of climate change has been considered.

The flood models have assessed 2.1 degrees of warming and a 16% increase on rainfall based on guidance from Auckland Council and the Ministry for the Environment. However, given the uncertainty of climate change effects in the future, the assessment has also considered a more severe climate change scenario based on the Representative Concentration Pathway (**RCP**) 8.5 which allows for 3.8 degrees of warming and a 32.7% increase on rainfall.

The results for 3.8 degrees of warming have been compared to those reported in the flood assessment for RCP 4.5 and areas where higher rainfall may increase flooding have been identified.

In the future it is possible that there may be different requirements for assessing climate change, however, at this time, the sensitivity analysis has been prepared to understand the risk of climate change associated with the proposed designations and enable decision makers to appropriately respond to this with the level of information available at the time of writing this assessment.

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

4 All Airport to Botany Bus Rapid Transit NoRs

This section assesses common or general flood matters across the entire Project corridor (i.e. all five NoRs). This section also recommends measures to avoid, remedy, or mitigate actual or potential adverse effects.

4.1 Positive effects

The positive effects associated with the Project include the potential to:

- Raise the existing road levels to preventing flood flows across the road and reducing flood hazard (where this is not limited by existing flooding effects upstream) for road users;
- Improve existing culvert capacities and/or provide new stormwater infrastructure which improve ponding and stream flow in the area; and
- Provide stormwater quality treatment and retention/detention for existing and proposed impervious areas.

4.2 Assessment of construction effects

The following construction effects apply to the entire Project. Based on the location of works in terms of overland flows or known flood extents in the vicinity, the proposed construction works which could result in flooding effects include:

- Construction of new culvert crossings or upgrading of existing culvert or bridge crossings;
- Realignment of existing overland flow paths;
- Works, such as regrading and raising levels, within existing floodplains; and
- Storage of materials and use of lay down areas within floodplains.

4.3 Recommended measures to avoid, remedy or mitigate construction effects

The proposed management and mitigation measures for construction effects across the Project are set out below.

General:

Flood hazard effects for the construction phase in existing high hazard areas should be addressed in a Construction Environmental Management Plan (**CEMP**). In preparing the CEMP, key matters to include are (but not limited to):

- Siting construction yards, laydown areas and stockpiles outside the predicted flood plains;
- Maintaining overland flow paths around / through areas of work;
- Minimising 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;
- Carrying out earthworks during the summer / dry months to reduce the risk of flooding; and
- Managing the overland flow paths to make sure flows are not diverted toward existing buildings or properties.

Construction of new and existing bridges, culvert crossings and stormwater devices:

There may be some temporary flooding risk associated with the works required for the construction of new and existing bridges, culverts and stormwater devices. However, the details of the construction methodology will be confirmed in the future during detailed design. It is expected that that the works can be carried out in a manner that appropriately manages these risks and this can be defined through the flood risk mitigation measures in the CEMP.

4.4 Assessment of operational effects

The assessment of operational effects for the Project is based on the 100 year flood model results for the pre-development (existing) terrain and considers the flooding extents at existing culvert crossings and along existing roads. The following matters have been considered as part of this assessment:

- Existing flooding and freeboard at key points identified from modelling the existing terrain;
- The potential of flooding on existing properties due to the new Project corridor geometry;
- Incremental changes to the corridor impervious area; and
- The mitigation measures set out in Section 4.5 have been designed so that flood effects are adequately addressed during the future detailed design stage of the Project and that adverse flood effects are avoided, remedied or mitigated.

4.5 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 are implemented (as required) 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); and
- No more than a 10% average increase of flood hazard (defined as flow depth times velocity) for the main access to authorised habitable dwellings.

In addition to the above, further mitigation measures that could be implemented include:

- Maintaining existing road levels within the corridor at overland flow paths and floodplains;
- 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 Project corridor and do not cross under the road;
- Increasing culvert sizes or pipe systems to manage changes to flood levels;
- Using storage within linear treatment devices, raingardens, wetlands or separate attenuation devices to reduce the peak flow increase due to changes in impervious area within the corridor; and
- Integrating development stormwater design requirements with adjacent development or wider upgrades to public infrastructure upstream and downstream of the proposed corridor.

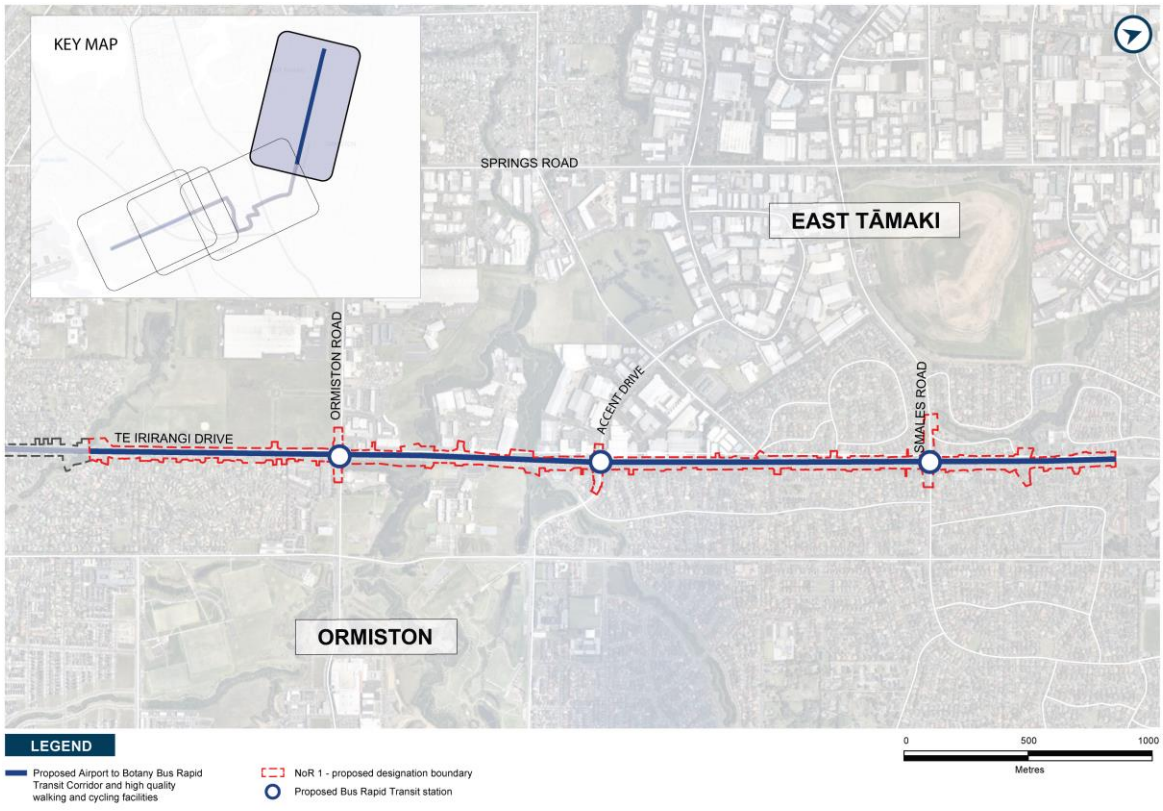
5 Airport to Botany Bus Rapid Transit NoR 1

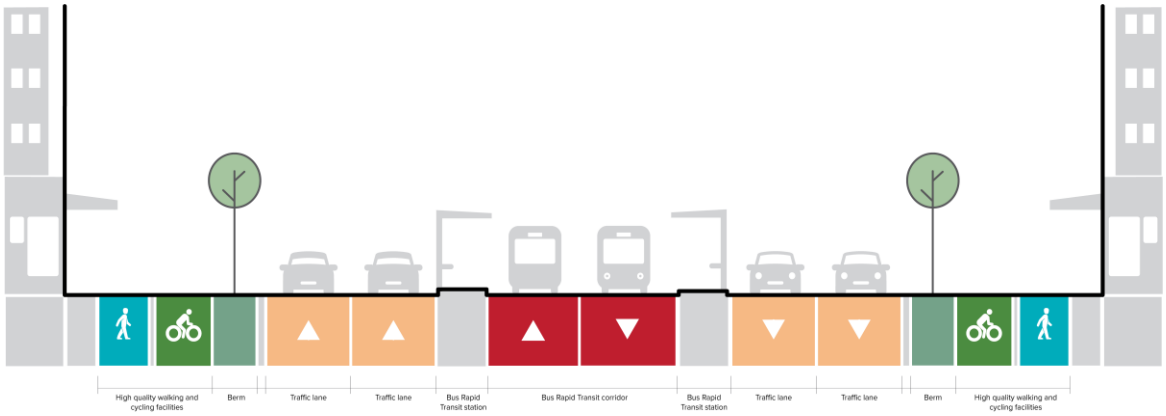
This section assesses specific flood matters relating to the NoR 1 corridor between Botany Town Centre, in the vicinity of Leixlep Lane and Rongomai Park.

5.1 Project features and proposed works

As set out in Table 6 below, the proposed works in NoR 1 include the widening of existing Te Irirangi Drive to accommodate a centre-running BRT corridor, two vehicle lanes in each direction and high quality walking and cycling facilities.

Table 6: Overview of NoR 1

NoR 1 – Botany Town Centre to Rongomai Park	
	
Key features	
BRT Corridor	Centre-running along Te Irirangi Drive
BRT Stations	• Smales Road Station; • Accent Drive Station; and • Ormiston Road Station.
Walking and cycling facilities	Walking and cycling facilities on both sides of the corridor
General traffic	Two lanes in each direction (existing)

Access	There is an existing central median along the majority of Te Irirangi Drive which restricts right-turn access
Speed environment	50km/h
Signalised intersections	• Te Irirangi Drive and Smales Road; • Te Irirangi Drive and Accent Drive; • Te Irirangi Drive and Bishop Dunn Avenue; and • Te Irirangi Drive and Ormiston Road.
Stormwater infrastructure	• Swales; and • Wetlands
NoR 1 typical cross section	
	

NoR 1 is generally limited to the existing road corridor width, therefore the proposed stormwater treatment devices are mainly linear treatment.

Proposed stormwater treatment devices include:

- **For Pakuranga Catchment:** Swales on Te Irirangi Drive near Wando Lane, near Shingleton Lane, near Gransa Lane and near Shedding Lane;
- **For Ōtara Creek/Flat Bush Catchment:** Rain Gardens on Te Irirangi Drive, Bishop Dunn Place; and
- New stormwater drains will be required on both sides of the road to direct the stormwater to the proposed treatment devices.

5.1.1 Stormwater catchment overview

NoR 1 lies within the Ōtara Creek / Flat Bush and Pakuranga Creek catchment models (see Section 3.5.2 for more detail). Along NoR 1 the corridor crosses three streams and two overland flow paths that drain by means of a bridge, culverts and an underground pipe network (see Figure 8).

5.1.2 Catchment characteristics

NoR 1 is predominantly zoned under the AUP:OP as Residential – Mixed Housing Suburban Zone, Residential – Mixed Housing Urban Zone, Open Space – Sport and Active Recreation Zone, Business – Light Industry Zone and Business – Mixed Use Zone. In terms of land use, the upstream area along this section of the Project is mainly residential development characterised by single homes, while the downstream areas are more open consisting of open space and large format commercial and industrial development.

Pakuranga Creek has a number of tributaries which are heavily modified.

Figure 3: NoR 1 in the context of the Pakuranga Creek catchment

For the Ōtara Creek / Flat Bush Catchment the main watercourses include Ōtara Creek, Stancombe Stream, Ormiston Stream, Murphy's Stream, Flat Bush School Road Stream and Killarney Stream. Streams within the catchment are generally characterised by poorly consolidated stream banks with a mixture of native and exotic vegetation.

Figure 4: NoR 1 corridor in the context of the Ōtara Creek / Flat Bush catchment

Key existing stormwater management assets in this section of the corridor in Ōtara Creek / Flat Bush Catchment include:

- Rongomai Park Wet Pond and Rongomai Park Dam;
- Preston Road Reserve Wet Pond and Preston Road Reserve Dam;
- Flat Bush Dam; and
- Sancta Maria Wet Pond.

The Stormwater Management Report prepared for Flat Bush identifies Flat Bush Dam as a significant quantity control structure attenuating water during extreme rainfall events to mitigate downstream flooding and forms part of a wider stormwater and flood management strategy for the catchment.

5.2 Assessment of construction effects and recommended measures to manage effects

Potential flooding effects during construction across the Project have been described in Section 4.2 above. Stream crossings are key sites for potential flooding effects during construction. NoR 1 includes the following stream crossings:

- 2500 dia culvert south of Treneary Lane;
- Bridge duplication south of Sancta Maria; and
- Box culverts south of Whetstone Road.

As set out in Section 4.3, the potential flooding effects during construction will be managed through flood risk mitigation measures set out in the CEMP for existing high flood hazard areas which is recommended to be a condition on the proposed designation.

5.3 Assessment of operational effects

This assessment of effects refers to the 100 year flood model results for the pre-development (existing) terrain and considers the flooding extents at the existing culvert crossing and significant areas alongside the existing road. The flood effects identified in NoR 1 already exist. As there are no significant changes proposed to the vertical alignment, these effects are generally unchanged.

Within NoR 1, the increase in impervious area is expected to be approximately 10%, which is due to the removal of the central grassed island being replaced with the BRT lanes. The higher peak runoff during the 100 year event can be reduced by the provision of storage within the linear treatment devices if required. Within the Pakuranga Creek catchment and the Flat Bush catchment, the corridor is in the lower half of both catchments, indicating that flood attenuation is not required.

The existing flood model has been reviewed and specific locations of interest have been assessed below.

5.3.1 Pakuranga Creek catchment

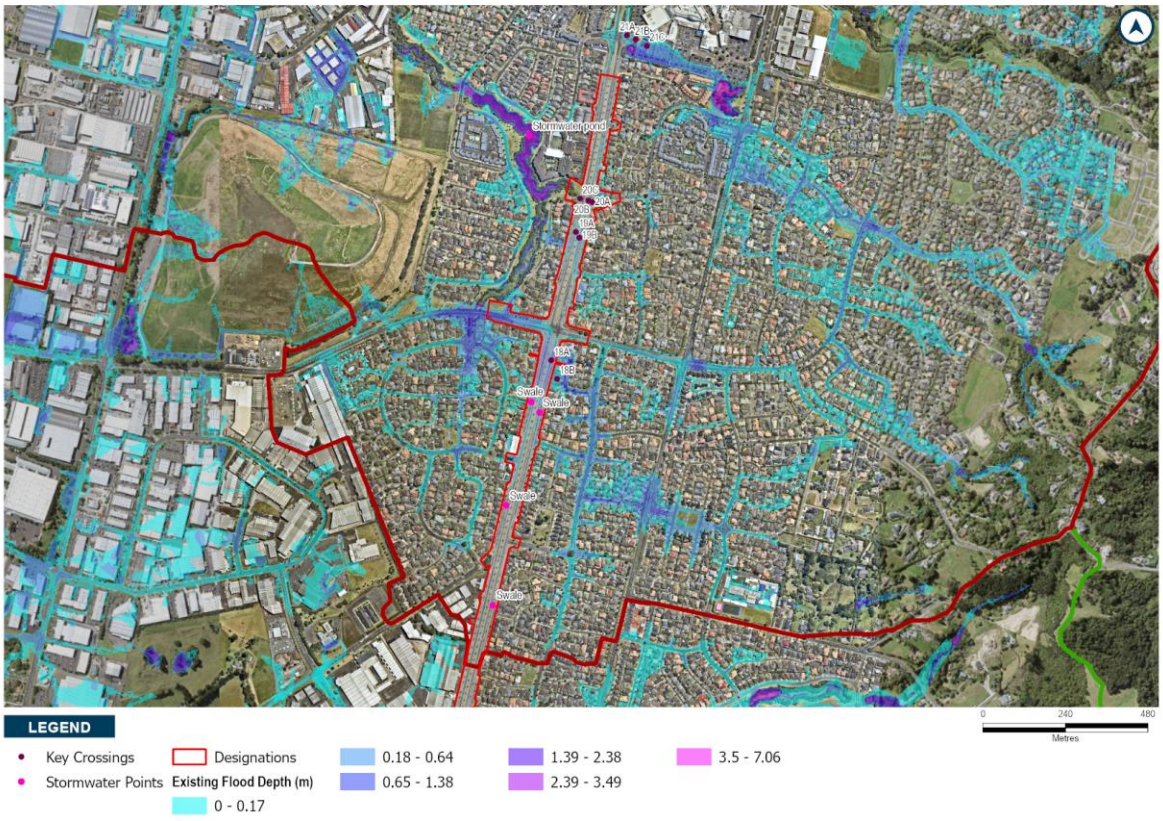


Figure 5: 100 year event for the proposed NoR 1 corridor (Pakuranga catchment)

At Point 20 the flood risk rating is negligible (see Table 7) and no further assessment of this location has been undertaken. Locations where the existing flood risk is moderate or high are discussed in more detail below.

Table 7: Rongomai Park to Botany Town Centre, in the vicinity of Leixlep Lane (NoR 1) existing flood levels at key locations

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	100 Year flood level (RL) pre-development	Existing flood risk rating
Te Irirangi Drive near Smales Road (Point 18A)	2050 mm dia. pipe network Road lvl RL 20.89 m	Road corridor	21.88 m	High risk Flood depth 0.98 m
18 Ardkeen Place (Point 18B)	Site lvl RL 22.09	House / building	22.18 m	Low risk Flood depth 0.09 m
Te Irirangi Drive near Kellaway Drive (Point 19A)	1350 mm dia. pipe network Road lvl RL 18.98	Road corridor	19.19 m	Moderate risk Flood depth 0.21 m
Te Irirangi Drive near Aaronville Way (Point 19B)	Road lvl RL 18.96	Road corridor	19.44 m	Moderate risk Flood depth 0.48 m
Te Irirangi Drive near Brinlack Drive (Point 20B)	Road lvl RL 20.16 m	Road corridor	18.12 m Upstream 17.61 m Downstream	Negligible risk Adequate freeboard Flood depth 0.00 m

5.3.1.1 Te Irirangi Drive and Smales Road intersection

The existing flood risk at the Te Irirangi Drive and Smales Road intersection (Location 18A) is high. The flood level is up to 0.98m deep with a 100 year flood level of 21.88 m. The flood enters the existing road corridor from the east and builds up in depth on the west side of the road until it can overflow through residential property to the west (see Point 18B) and along Te Irirangi Drive to the north to the intersection with Smales Road (where the lowest road level is about RL 21.5 m). The intersection levels prevent overland flow from this location which is the low point.

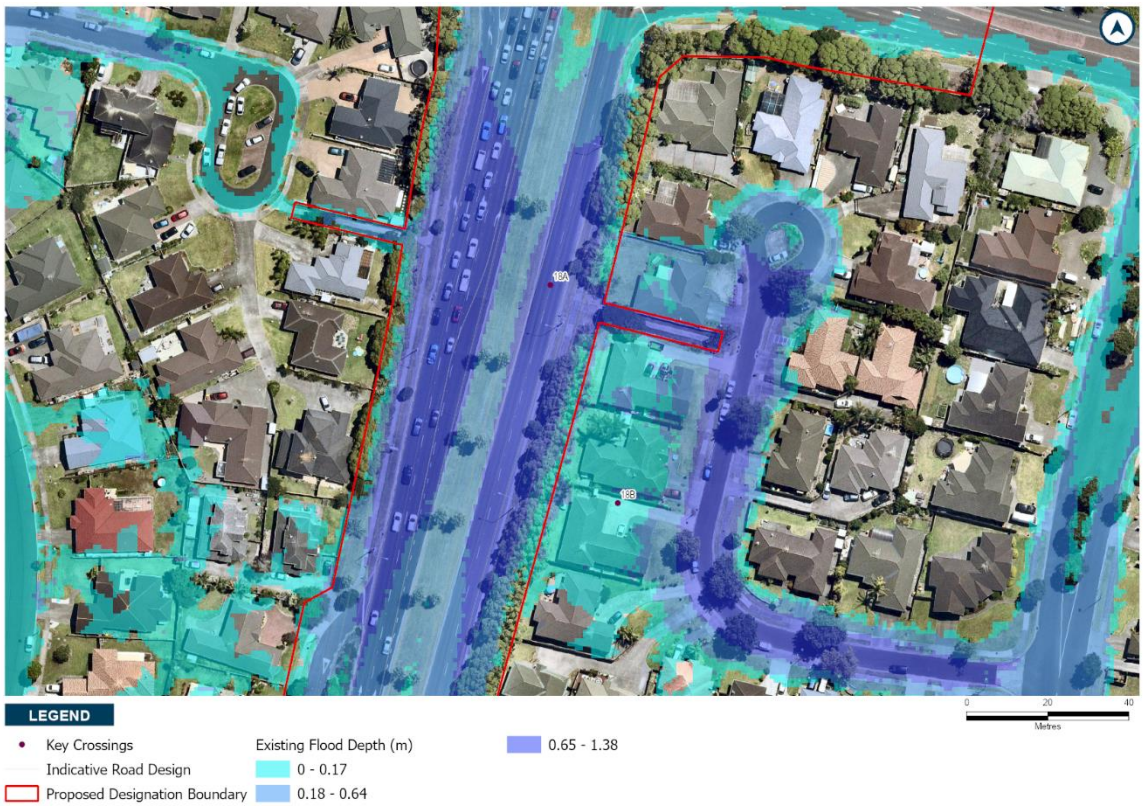


Figure 6: 100 year ARI event for the proposed NoR 1 corridor at Location 18A

In addition to the levels there is potentially a lack of network capacity. The network east of the existing road corridor consists of several branches of pipes up to 2100 mm diameter all drained by one 2050 mm diameter pipe to Kellaway Reserve. There are no details of the pipe network to the west side of the existing corridor and further investigation is required at the future detailed design stage of the Project. It is recommended that the levels of the final design for the Project should not increase unless an overland flow path or significant additional pipe capacity is provided.

5.3.1.2 Te Irirangi Drive near Kellaway Drive

At Te Irirangi Drive near Kellaway Drive (Location 19), a moderate flood risk exists with flood depths up to 0.48 m predicted on the eastern side of the existing road including the footpath and cycleway (Point 19B) and up to 0.21 m are on the western side of the road (Point 19A). Water moves across the road and pools before flowing to the unnamed stream on the western side of Kellaway Drive.

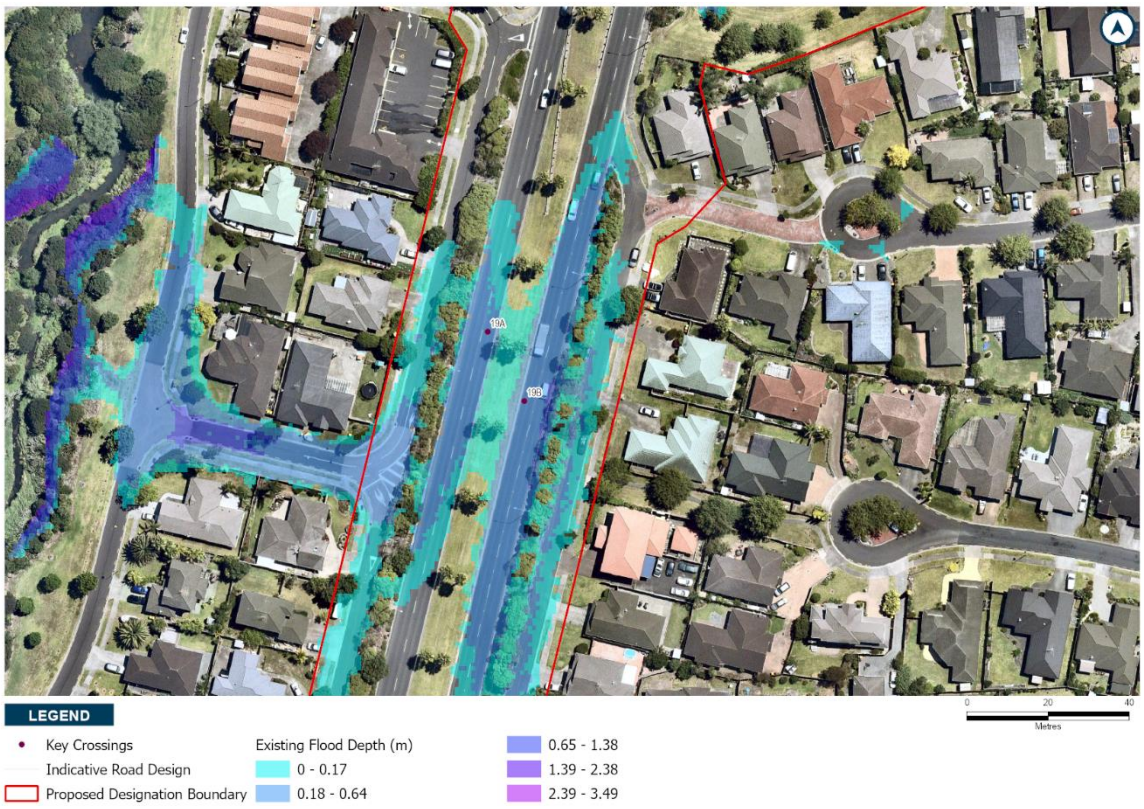


Figure 7: 100 year ARI event for the proposed NoR 1 corridor at Location 19A and 19B

It is recommended that the levels of the final design for the Project should not increase unless an enlarged or new overland flow path or significant additional pipe capacity is provided. Further checking of the pipe capacity will need to be carried out at the detailed design stage to refine this estimate and determine the extent of the hazard. Methods to mitigate the risk can be assessed further at the detailed design stage and it is considered that the proposed designation has sufficient space for a number of mitigation options to be applied.

5.3.2 Ōtara Creek / Flat Bush catchment

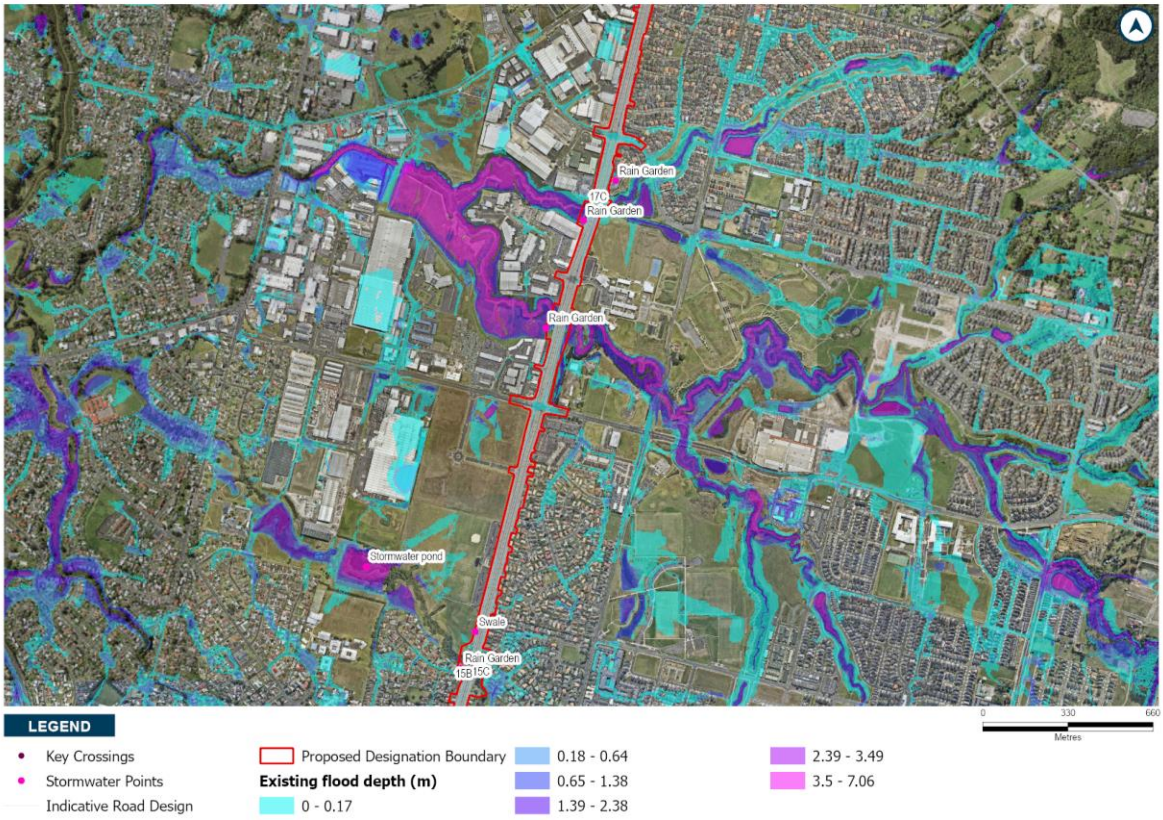


Figure 8: 100 year event for the proposed NoR 1 corridor (Ōtara Creek/Flat Bush catchment)

At Locations 16 and 17 the flood risk rating is negligible (see Table 8) and no further assessment of these locations has been undertaken. Location 15, where the flood risk high, has been discussed in more detail below.

Table 8: Rongomai Park to Botany Town Centre, in the vicinity of Leixlep Lane (NoR 1) existing flood levels at key locations

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	100 Year flood level (RL) pre-development	Existing flood risk rating
Unnamed Stream Crossing near Rongomai park (Point 15B)	Road/bridge lvl RL 18.43 m 450 mm dia pipe network	Road corridor	18.65 m	Moderate risk Flood depth 0.33 m
Whetstone Road near Te Irirangi Road (Point 15A)	Site lvl RL 18.10 m	Road corridor	18.66 m	High risk Flood depth 0.65 m
Ōtara Stream Bridge (Points 16A to 16C)	Ōtara Stream Bridge lvl RL 17.66 m	Road corridor	16.27 m Upstream 16.15 m Downstream	Negligible risk Adequate freeboard Flood depth 0.00 m

Unnamed Stream Crossing near Treneary Lane (Points 17A to 17C)	2500 mm arched pipe culvert Road lvl RL 18.87 m	Road corridor	18.41 m Upstream 15.96 m Downstream	Negligible risk Adequate freeboard Flood depth 0.00 m

5.3.2.1 Unnamed Stream Crossing near Rongomai Park

At Te Irirangi Drive unnamed stream crossing (Point 15B) the existing flood risk is considered moderate with a flood depth of 0.33 m during the 100 year event. Buses would be able to continue to utilise the BRT corridor at depths of up to 0.3 m and would therefore only be impacted in extreme weather events.

The adjacent land use at Whetstone Road near Te Irirangi Road (Point 15A) are residential with no direct access to Te Irirangi Road. There is an opportunity to raise to road at the culvert or place additional culverts to reduce the flooding risk. The proposed designation boundary is considered sufficiently wide at this point to enable localised raising of the carriageway or culvert duplication, and therefore the need to improve flood resilience can be considered during the future detailed design phase.

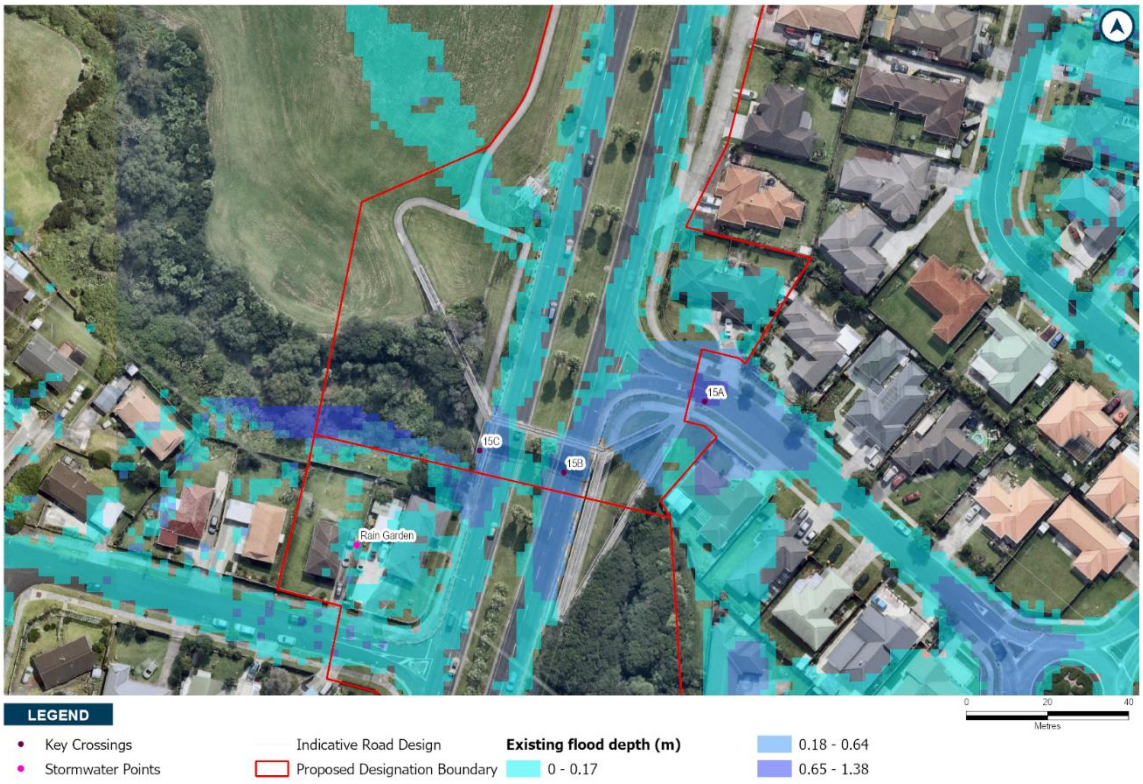


Figure 9: 100 year ARI event for the proposed NoR 1 corridor at Location 15

5.4 Recommended measures to avoid, remedy or mitigate operational effects

There is a high existing flood risk identified at the intersection of Te Irirangi Drive and Smales Road (Point 18A). Potential mitigation options at this location include:

- Lowering the intersection to allow flood water to move more easily from the trapped low point onto Smales Road and reduce flood levels;
- Temporary road diversions or safe alternative routes during a flood event; and
- Additional pipe capacity and inlets, particularly on the western side of the road.

At Te Irirangi Drive near Kellaway Drive (Point 19A and 19B) there is a moderate flood risk rating due to existing flood effects. Potential mitigation at this location is to:

- Provide additional or upsized piped drainage and/or greater inlet capacity to reduce the risk of flooding.

At the Te Irirangi Drive unnamed stream crossing near Rongomai Park (Point 15B), investigations into raising the road or adding additional culvert capacity should be undertaken during the future detailed design stage.

It is recommended that the outcomes identified in Section 4.5 apply as a proposed condition on this NoR.

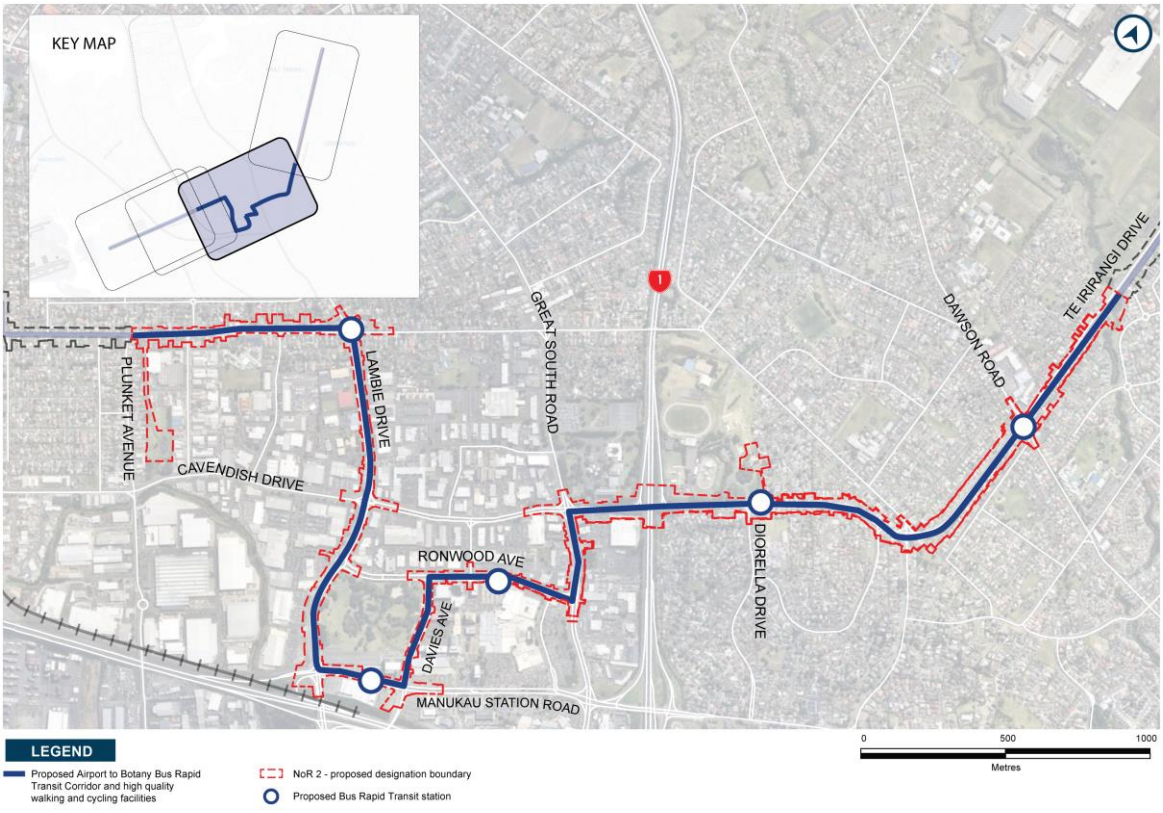
6 Airport to Botany Bus Rapid Transit – NoR 2

This section assesses specific flood matters relating to NoR 2, the Project corridor between Rongomai Park and Puhinui Station, in the vicinity of Plunket Avenue.

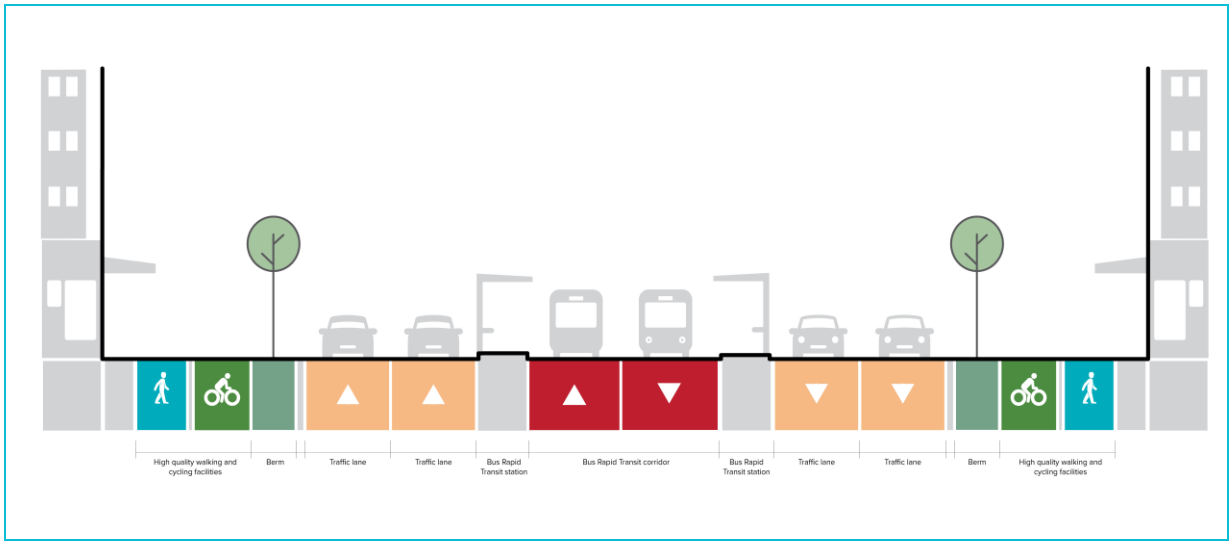
6.1 Project features and proposed works

As set out in Table 9 below, the proposed works in NoR 2 include the widening of several existing roads to accommodate a centre-running BRT corridor, vehicle lanes and high quality walking and cycling facilities.

Table 9: Overview of NoR 2

NoR 2 – Rongomai Park to Puhinui Station, in the vicinity of Plunket Avenue	
	
Key features	
BRT Corridor	Centre-running for the majority of the corridor along Te Irirangi Drive, Great South Road, Ronwood Avenue, Manukau Station Road, Lambie Drive, and Puhinui Road West-running on Davies Avenue along the edge of Hayman Park
BRT Stations	• Dawson Road Station; • Diorella Drive Station; • Ronwood Avenue Station; • Manukau Station; and

	• Corner of Lambie Drive and Puhinui Road Station.
Walking and cycling facilities	Walking and cycling facilities on both sides of the road
General traffic	• Two lanes in each direction along Te Irirangi Drive, Great South Road, Ronwood Avenue, Manukau Station Road, and Lambie Drive • One-way single lane along Davies Avenue • One lane in each direction along Puhinui Road
Access	Existing central medians limit right turn access on Te Irirangi Drive, Great South Road, Ronwood Avenue, and Lambie Drive. New signalised intersection at Mitre 10 and Bunnings Warehouse on Lambie Drive. Priority access for fire engine movements across the BRT corridor at Papatoetoe Fire Station.
Speed environment	• 30 km/h on Ronwood Avenue and Davies Avenue; and • 50 km/h on Te Irirangi Drive, Great South Road, Manukau Station Road, Lambie Drive and Puhinui Road.
Signalised intersections **(new intersections in bold)**	• Te Irirangi Drive and Dawson Road; • Te Irirangi Drive, Boundary Road and Hollyford Drive; • Te Irirangi Drive and Diorella Drive; • Te Irirangi Drive, Great South Road and Cavendish Drive; • Great South Road and Ronwood Avenue; • Ronwood Avenue and Davies Avenue; • Davies Avenue, Wiri Station Road and Manukau Station Road; • Manukau Station Road and Lambie Drive; • **Mitre 10 and Bunnings Warehouse;** • **Lambie Drive and Ronwood Avenue;** • Lambie Drive and Cavendish Drive; • Lambie Drive and Puhinui Road; and • **Puhinui Road and Plunket Avenue.**
Stormwater infrastructure	• Swales; and • Wetlands
NoR 2 typical cross section	



A summary of the proposed stormwater treatment in NoR 2 includes:

- Rain gardens on Te Irirangi Drive and near the Manukau Sports Bowl for the Ōtara Creek / Flat Bush catchment;
- Stormwater pond enhancement at Puhinui Doman and Hayman Park for the Puhinui Catchment; and
- New stormwater drains will be required on both sides of the road to direct the stormwater to the proposed treatment devices.

6.1.1 Stormwater catchment overview

NoR 2 lies within the Ōtara Creek / Flat Bush and Puhinui catchments (see Section 3.5.2 for more detail). Along NoR 2 the corridor crosses four overland flow paths that drain by means of an underground pipe network (see Table 11).

6.1.2 Catchment characteristics

The land is zoned as per AUP:OP as Business – Light Industry Zone, Business – Metropolitan Centre Zone, Business – General Business Zone, Residential – Mixed Housing Suburban Zone, Open Space – Informal Recreation Zone and Open Space – Sport and Active Recreation Zone. The majority of land adjacent to the corridor is highly developed. There are existing established residential developments to the north of the proposed corridor along Puhinui Road. Areas to the south of the proposed corridor through Lambie Drive, Ronwood Avenue and Great South Road include existing commercial and industrial development.

Figure 10: NoR 2 in the context of the Ōtara Creek / Flat Bush catchment

Key existing stormwater management assets in this section of the corridor in the Puhinui Catchment include:

- Wet Ponds at Puhinui Domain, Lambie Drive On-Ramp and Off-Ramp and Hayman Park; and
- AT owned stormwater device at 154 Puhinui Road (StormFilter).

Figure 11: NoR 2 in the context of the Puhinui catchment

6.2 Assessment of construction effects and recommended measures to manage effects

Potential flooding effects during construction across the Project have been described in Section 4.2 above. In NoR 2, the proposed upgrade of the stormwater pond at Hayman Park is located within flood plain and overland flow path.

As set out in Section 4.3 above, the potential flooding effects during construction, including where works are within a flood plain will be managed through flood risk mitigation measures captured in the CEMP for existing high flood hazard areas.

6.3 Assessment of operational effects

This assessment of effects refers to the 100 year flood model results for the pre-development (existing) terrain and considers the flooding extents at the existing culvert crossing and significant areas alongside the existing road. The flood effects identified in NoR 2 already exist. As there are no significant changes to the vertical alignment, these effects are generally unchanged.

Within NoR 2 the increase in impervious area is expected to be:

- Approximately 10% - 15% within the Ōtara Creek / Flat Bush catchment; and
- Approximately 5% - 10% within the commercial area of the Puhinui catchment.

Within the Ōtara Creek catchment and the Puhinui catchment, the corridor is in the upper third of both catchments, indicating that flood attenuation for increased impervious area may be required.

The higher post development peak runoff during the 100 year event can be reduced by the provision of storage within the proposed raingardens near the Manukau Sports Bowl and the proposed new wetland within Hayman Park. Linear treatment is proposed within the Puhinui catchment along Lambie Drive. The small effect from increased impervious area and peak flow in the existing commercial area can be mitigated by providing flood attenuation controls at the regularly spaced tree pits.

6.3.1 Ōtara Creek / Flat Bush catchment

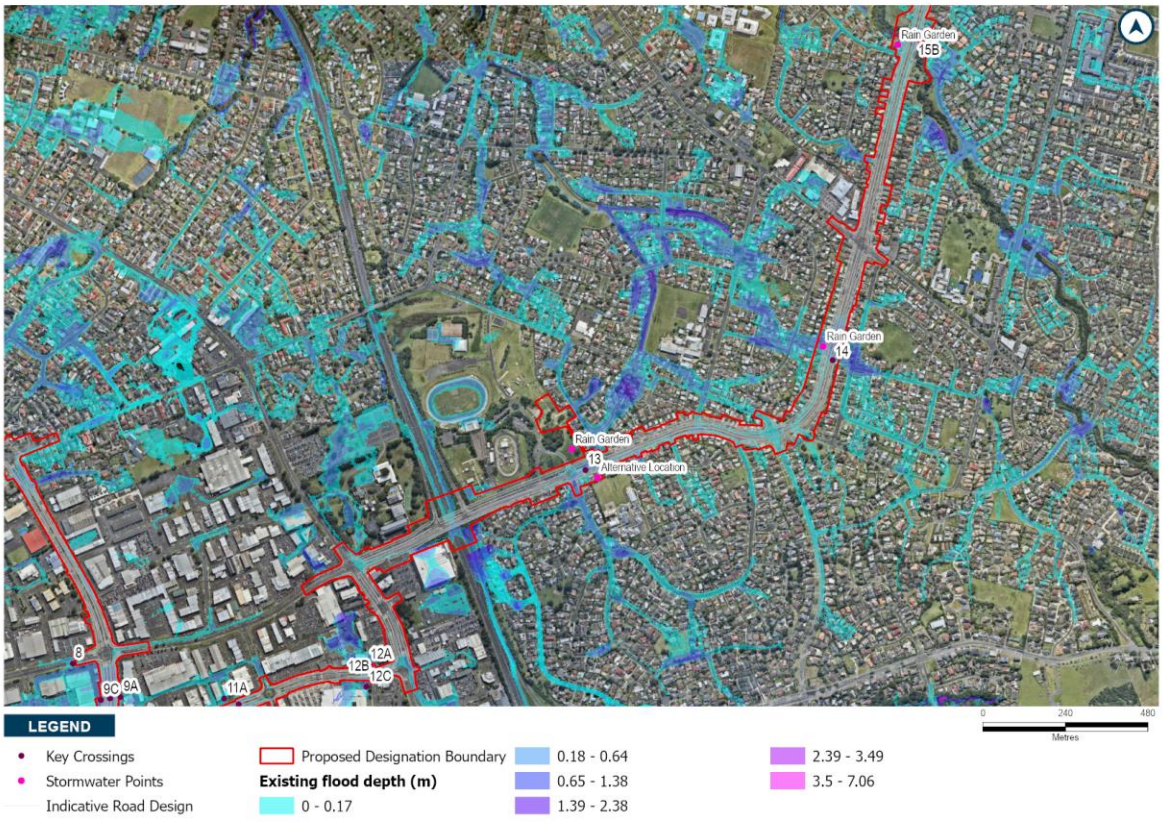


Figure 12: 100 year event for the proposed NoR 2 corridor (Ōtara Creek / Flat Bush catchment)

The existing flood model has been reviewed and specific locations of interest have been assessed below.

At Locations 13 and 14 the flood risk rating is low or negligible (see Table 10) and no further assessment of these locations has been undertaken. Locations where the flood risk is moderate or high are discussed in more detail below.

Table 10: NoR 2 (Ōtara Creek / Flat Bush Catchment) existing flood levels at key locations

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	100 Year flood level (RL) pre-development	Existing flood risk rating
1 Ronwood Avenue (Point 12A)	Site lvl RL 26.64 m	Commercial building / driveway	27.30 m	High risk Flood depth 0.65 m

Ronwood Avenue near Great South Road (Point 12B)	Road lvl RL 26.79 m	Road corridor	27.30 m	High risk Flood depth 0.51 m
Manukau Westfield near Ronwood Avenue (Point 12C)	Site lvl RL 27.04 m	Carpark	27.30 m	Moderate risk Flood depth 0.26 m
Te Irirangi Drive near Diorella Drive Road (Point 13)	Road lvl RL 28.44 m	Road corridor	28.46 m	Low risk Flood depth 0.11 m
Te Irirangi Drive near Boundary Road (Point 14)	Road lvl RL 17.58 m	Road corridor	29.93 m	Negligible risk Flood depth 0.03 m

At Location 12 the existing flood risk rating has identified a high flood risk. The flood depth is up to 0.65 m to the north of Ronwood Avenue where flooding is confined to the carpark area and up to 0.51 m on the road centreline. It is recommended that further investigation into the effects on adjacent buildings to the south at 655 Great South Road is required.

It is also recommended that a new overland flow path parallel to Ronwood Avenue running down to Hayman Park is considered at the detailed design stage. This overland flow path could be combined with the berm or walking and cycling facility on the south side of the corridor. If this is not feasible, it is recommended that the vertical alignment on Ronwood Avenue near Leyton Way is not raised to avoid exacerbating flooding upstream.

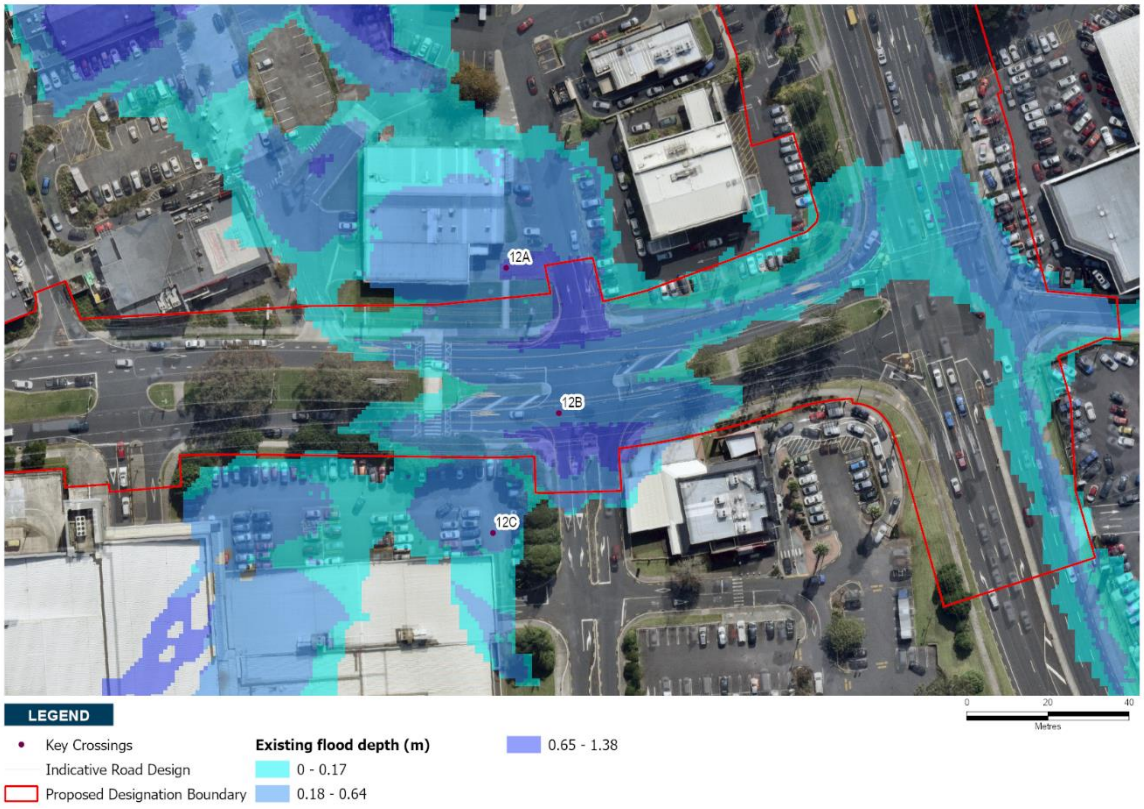


Figure 13: 100 year ARI event for the proposed NoR 2 corridor at Location 12

6.3.2 Puhinui catchment

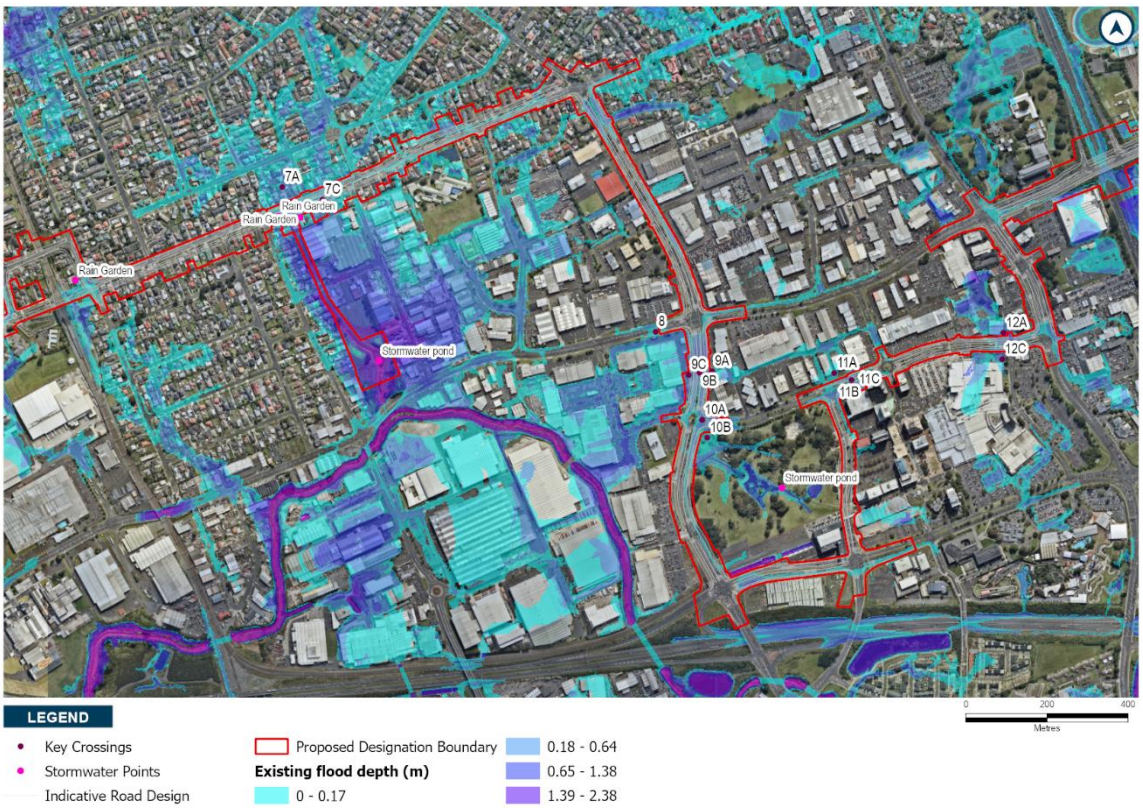


Figure 14: 100 year event for the proposed NoR 2 corridor (Puhinui catchment)

At Point 8 the maximum flood depth is 0.09 m and the risk rating is considered low (see Table 11) this location has not been considered further. For those locations where the flood risk is moderate or high are discussed in more detail below.

Table 11: NoR 2 (Puhinui Catchment) existing flood levels at key locations

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	100 Year flood level (RL) pre-development	Existing flood risk rating
135A Puhinui Road (Point 7A)	Site lvl RL 17.69 m	Building / house driveway	17.76 m	Low risk Flood depth 0.07 m
Puhinui Road near Bledisloe Street (Point 7B)	600 mm dia. pipe network Road lvl RL 17.58 m	Road corridor	17.68 m	Low risk Flood depth 0.11 m
142 Puhinui Road (Point 7C)	Site lvl RL 17.44 m	Building / house driveway	17.64 m	High risk Flood depth 0.20 m
Cavendish Drive near Lambie Drive (Point 8)	Site lvl RL 19.68 m	Road corridor	19.77 m	Low risk Flood depth 0.09 m
42 Lambie Drive (Point 9A)	Site lvl RL 19.56 m	Carpark	19.58 m	Negligible risk Flood depth 0.02 m

Lambie Drive near Cavendish Drive (Point 9B)	Road lvl RL 18.68 m	Road corridor	19.01 m	Moderate risk Flood depth 0.33 m
Cnr Lambie Drive and Cavendish Drive (Point 9C)	Cnr Lambie Drive and Cavendish Drive Road lvl RL 18.04 m	Carpark	18.69 m	High risk Flood depth 0.65 m
Lambie Drive Ronwood Avenue Intersection (Point 10A)	Road RL 19.17 m	Road corridor	19.57 m	Moderate risk Flood depth 0.40 m
Hayman Park Near Lambie Drive carpark (Point 10B)	Site lvl RL 19.76 m	Open space / park	19.84 m	Low risk Flood depth 0.09 m
11 Ronwood Avenue (Point 11A)	Site lvl RL 24.06 m	Commercial building / carpark	24.08 m	Negligible risk Flood depth 0.02 m
Ronwood Avenue near Davie Avenue (Point 11B)	Road lvl RL 24.36 m	Road corridor	24.37 m	Negligible risk Flood depth 0.00 m
2 Davies Avenue (Point 11C)	Site lvl RL 24.24 m	Carpark	24.45 m	Moderate risk Flood depth 0.21 m

6.3.2.1 Puhinui Road

At Location 7 the residential development downstream (Point 7C) has a flood depth between 0.15 m to 0.5 m and therefore is considered to have a high-risk rating with respect to flood effects. At Location 7 the catchment drains by means of an underground pipe network into the Puhinui domain and discharges under Cavendish Drive into Puhinui Creek. The drainage network has 600 to 1500 mm diameter pipes which has been duplicated with 900 mm diameter pipes beneath the upstream extent of flooding.

Raising the vertical alignment of the existing road would affect a significant number of houses (approximately 200 houses) upstream and therefore the current road crest level should not be raised. The downstream flooding covers a wide area with a relatively flat hydraulic gradient. Further mitigation could entail temporary flood management options (such as temporary road diversions) during large flood events.

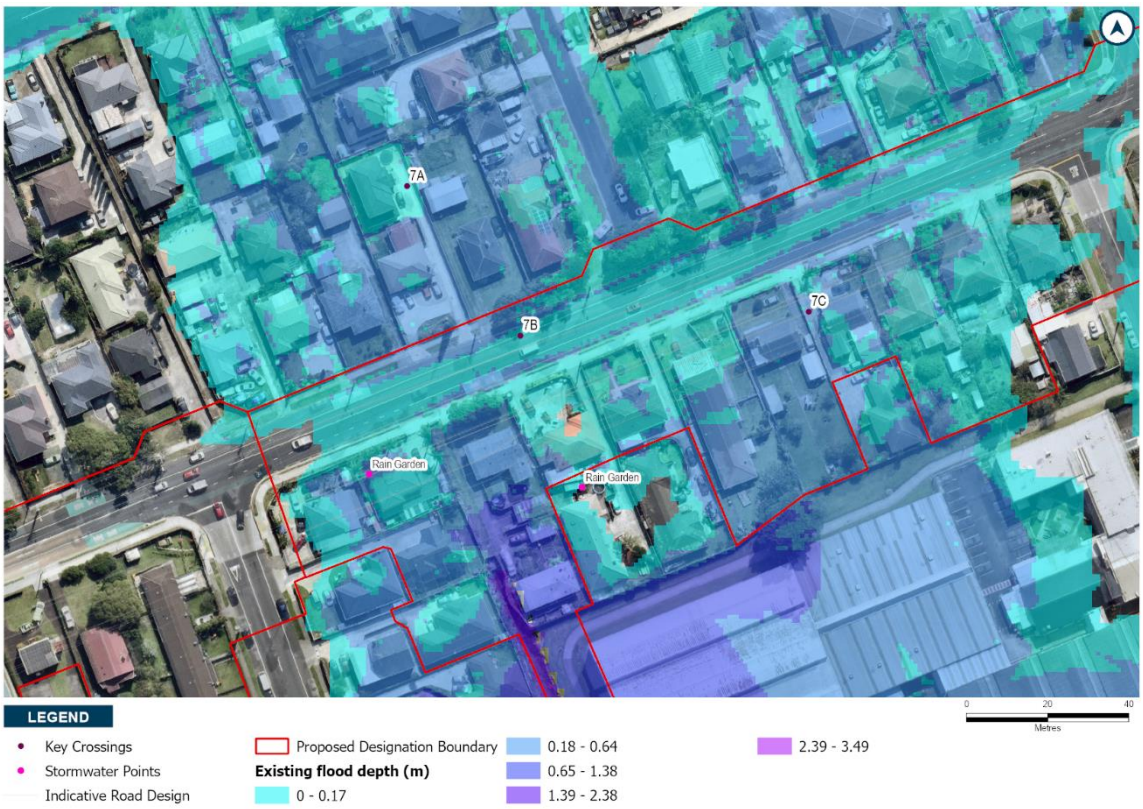


Figure 15: 100 year ARI event for the proposed NoR 2 corridor at Location 7

6.3.2.2 Lambie Drive

The road overtops at Point 9B with flood levels 0.33 m above existing road level for the 100 year ARI event. Upstream of this crossing the flood risk is negligible (Point 9A) at 0.02 m flood depth. However downstream of this crossing (Point 9C), flooding is controlled by downstream constrictions and a large area of deeper flooding forms on the west side of Lambie Drive. The flood depth is considered a high flood risk with flood depths up to 0.65 m predicted in the 100 year ARI.

Operational management options (such as warning signage or temporary closures) could be considered to reduce the exposure of pedestrians and cyclists along the proposed walking and cycling facilities.

At Points 10A and 10B water enters the road from Hayman Park. Raising the intersection so that water is contained within the park could reduce the hazard.

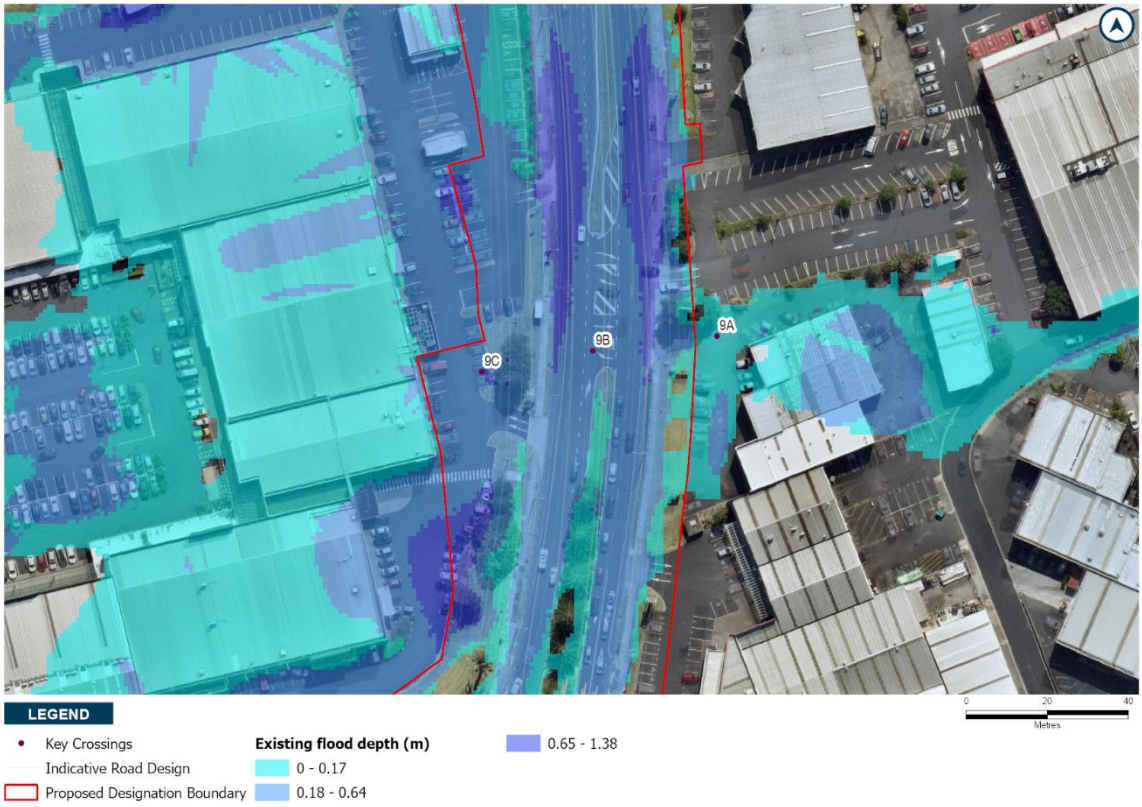


Figure 16 100 year ARI event for the proposed NoR 2 corridor at Location 9

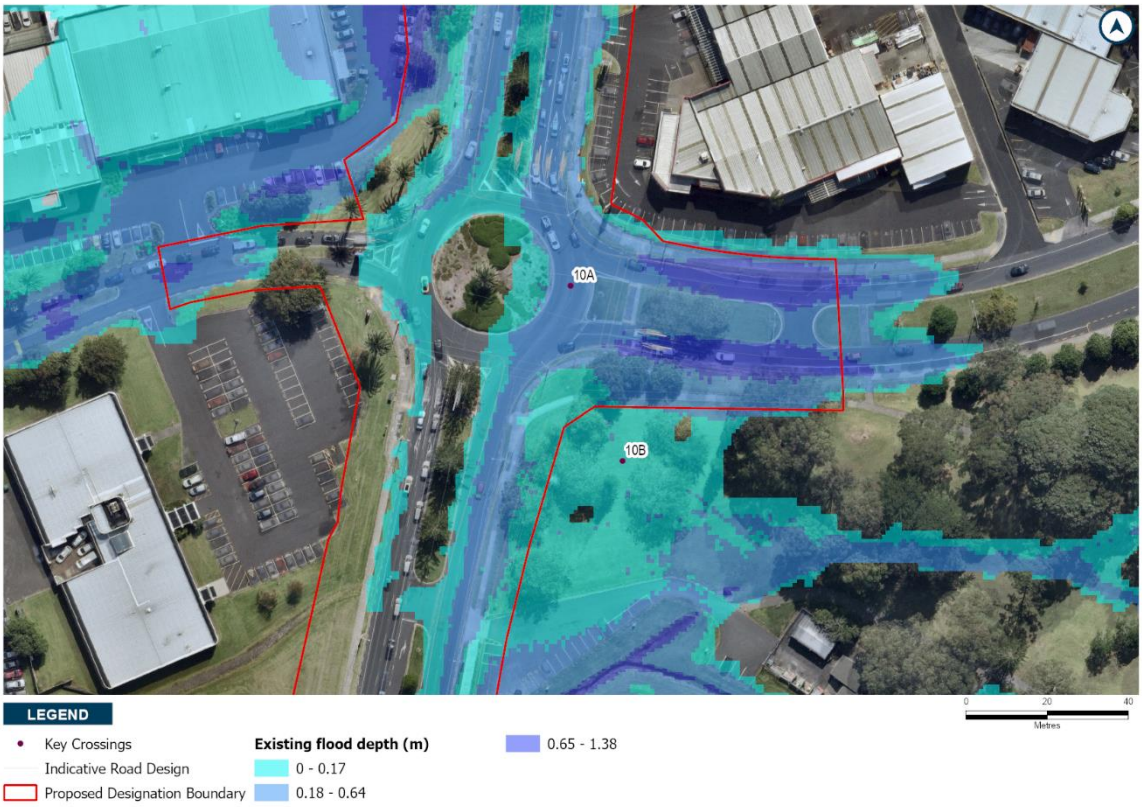


Figure 17: 100 year ARI event for the proposed NoR 2 corridor at Location 10

6.3.2.3 Ronwood Avenue

At Location 11, the vertical alignment of the Davies Avenue / Ronwood Avenue intersection cause water to pond on the south-east side of the road. Recommended mitigation includes reducing the level of Davies Avenue to allow overland flow to discharge into Hayman Park and minimise ponding.

Figure 18: 100 year ARI event for the proposed NoR 2 corridor at Location 11

6.4 Recommended measures to avoid, remedy or mitigate operational effects

There is an existing high flood risk at Ronwood Avenue near Great South Road (Point 12B). Potential mitigation options at this location include:

- A new overland flow path parallel to Ronwood Avenue running down to Hayman Park is investigated at detailed design;
- Not raising the road crest of the new alignment on Ronwood Avenue near Leyton Way; and
- Using a berm or walking and cycling facilities on the south side of the corridor as an overland flow path to reduce flood risk.

There is a high flood risk identified at the corner of Lambie Drive and Cavendish Drive (Point 9C), where there is flood plain and flood prone land. Potential mitigation options at this location include:

- Increasing the vertical alignment at the corner of Lambie Drive and Cavendish Drive provided that upstream flood risk is not increased; and
- Investigating temporary road diversions or safe alternative routes during a flood event.

At the Lambie Drive / Ronwood Avenue Intersection (Point 10A) there is a moderate existing flood risk rating. Potential mitigation options at this location include:

- Raising the intersection to contain flood water in Hayman Park.

There is also an existing high flood risk identified at Davies Avenue / Ronwood Avenue intersection (Point 11C). Potential mitigation options at this location include:

- Reducing the level of Davies Avenue to direct overland flow to Hayman Park.

At Ronwood Avenue near Leyton Way, potential mitigation for an existing high flood risk affecting the road corridor and some commercial development includes:

- Keeping the current vertical alignment; and
- Providing additional piped drainage, greater inlet capacity or creating an overland flow path parallel to the road.

There is an existing high flood risk identified at Puhinui Road, where there is flood plain and flood prone land. At this location mitigation options are limited due to development either side of the proposed designation. Potential mitigation options at this location includes:

- Keeping the current vertical alignment along Puhinui Road; and
- Investigating temporary road diversions or safe alternative routes during a flood event.

It is recommended that the outcomes identified in Section 4.5 apply as a proposed condition on this NoR.

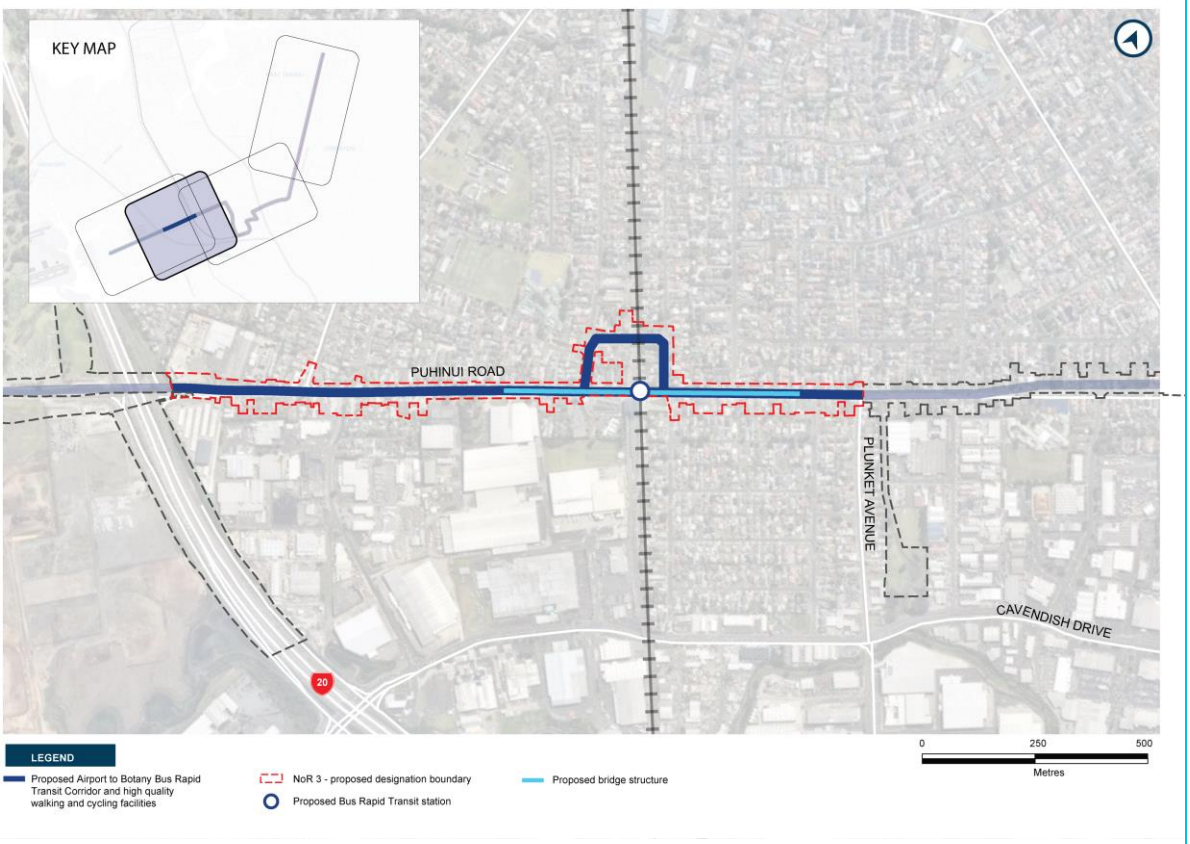
7 Airport to Botany Bus Rapid Transit – NoR 3

This section assesses specific flood matters relating to NoR 3, the Project corridor between Puhinui Station, in the vicinity of Plunket Avenue and the SH20/20B Interchange.

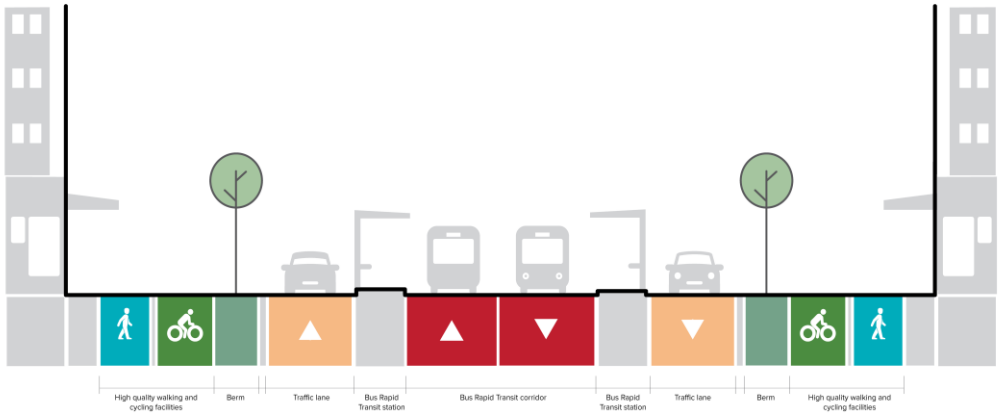
7.1 Project features and proposed works

As set out in Table 12 below, the proposed works in NoR 3 include the widening of the existing Puhinui Road to accommodate a centre-running BRT corridor, vehicle lanes and high quality walking and cycling facilities.

Table 12: Overview of NoR 3

NoR 3 – Puhinui Station, in the vicinity of Plunket Avenue to SH20/20B Interchange	
	
Key features	
BRT Corridor	Centre-running along Puhinui Road connecting to the Puhinui Station concourse via a new BRT bridge structure
BRT Stations	Puhinui Station
Walking and cycling facilities	• Walking and cycling facilities on both sides of the corridor; and • Walking and cycling facilities will be provided along Cambridge Terrace, Bridge Street and Kenderdine Road.

General traffic	One lane in each direction on Puhinui Road
Access	Limited right turn access
Speed environment	50km/h
Signalised intersections	• Puhinui Road and Noel Burnside Road; and • Puhinui Road and Wyllie Road.
Stormwater infrastructure	Wetland
NoR 3 typical cross section	



The widening of the proposed Project corridor is predominantly to the south of Puhinui Road. Proposed stormwater treatment devices in NoR 3 include:

- Rain gardens on Puhinui Road, Cambridge Street, Noel Burnside Road (East), Noel Burnside Road (West).

In addition to installing the rain garden, works will be required to isolate the Project corridor catchment from the existing stormwater network catchment to this point.

7.1.1 Stormwater catchment overview

NoR 3 is within the Puhinui Creek catchment (see Section 3.5.2 for more detail). Along NoR 3 the corridor crosses three major overland flow paths by means of an underground pipe network. Existing flood plain and flood prone areas are present on both sides of the road.

7.1.2 Catchment characteristics

NoR 3 is predominantly zoned under the AUP:OP as Business - Light Industry Zone, Residential – Mixed Housing Suburban Zone, Open Space – Sport and Recreation Zone and Open Space – Community Zone. In terms of land use the area contains a mixture of open space and established residential development dominated by single dwellings alongside industrial land use to the east of SH1. Adjacent to NoR 3, the urban form is mainly residential development described above.

Puhinui Stream is a heavily modified stream in places. The stream generally flows west towards Manukau Harbour.

An existing stormwater management asset is located in this section of the corridor in the Puhinui Creek catchment which is a stormwater pond located in Aerovista Place Reserve.

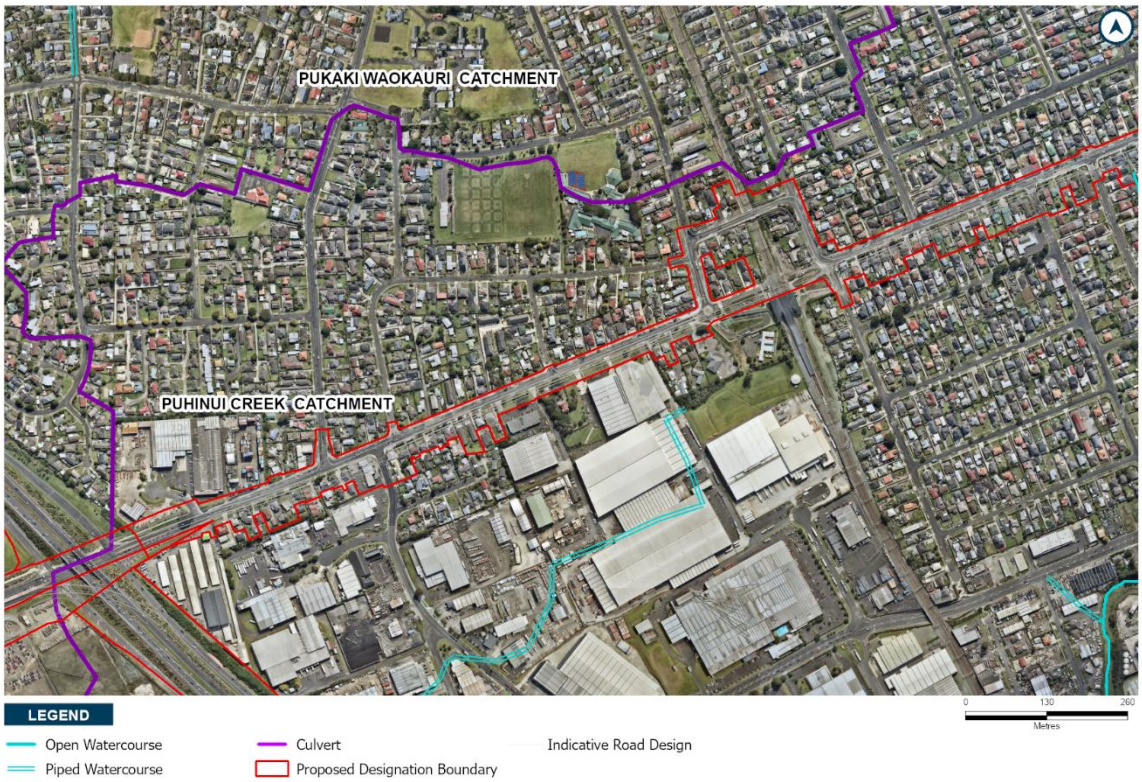


Figure 19: NoR 3 corridor in the context of Puhinui Creek catchment

7.2 Assessment of construction effects and recommended measures to manage effects

Potential flooding effects during construction across the Project have been described in Section 4.2 above. Stream crossings are key sites for potential flooding effects during construction, NoR 3 includes the following stream crossing:

- 1500 mm diameter culvert at 152 Puhinui Road.

A 300 m stretch of Puhinui Road and the proposed upgraded stormwater pond at Puhinui Domain are located within flood plain and overland flow path.

As set out in Section 4.3, the potential flooding effects during construction, including where works are within the floodplain it will be managed through flood risk mitigation measures set out in the CEMP for existing high flood hazard areas.

7.3 Assessment of operational effects

This assessment of effects refers to the 100 year flood model results for the pre-development (existing) terrain and considers the flooding extents at the existing culvert crossing and significant areas

alongside the existing road. The flood effects identified in NoR 3 already exist. As there are no significant changes to the vertical alignment, these effects are generally unchanged.

Within NoR 3 the increase in impervious area is expected to be:

- Approximately 10% to 15% within the residential areas of the Puhinui catchment.

The corridor is in the upper third of the catchment, indicating that flood attenuation may be required. The corridor runoff will be treated by a combination of existing ponds and proposed raingardens.

Between Lambie Drive and the Puhinui Station the corridor is 1.4 km long, with 0.5 km of this below the existing 100 year flood level. Raingardens are proposed in selected locations for treatment to enhance the downstream channel into, and the area around the Puhinui Domain pond. The Puhinui Domain pond is already designed to provide some attenuation in smaller events. As additional storage cannot take up existing storage within the floodplain, if further attenuation is required, the proposed designation boundary provides sufficient space to accommodate this alongside the corridor adjacent to the flood plain (likely at 166 to 176 Puhinui Road).

Between the Puhinui Station and SH20 the corridor is 1.0 km long, with existing 100 year flooding at the intersection with Noel Burnside Place. There is an existing treatment device downstream which is proposed to be used for treatment. The network carrying the flow to the existing pond will be affected by the flooding. If required, there is sufficient space within the designation boundary for flow attenuation adjacent to the corridor at 266 Puhinui Road and 302 to 306 Puhinui Road.

Figure 20: 100 year event for the proposed NoR 3 Corridor

The existing flood model has been reviewed and specific locations of interest have been addressed below.

At Location 6 the flood risk rating is low (see Table 13) which is likely a result of undersized drainage system size (currently 450 mm diameter maximum). Recommended mitigation includes increasing the pipe sizes to reduce the risk of flooding.

Locations where the flood risk is moderate has been discussed in more detail below.

Table 13: Puhinui Section (NoR 3) existing flood levels at key locations

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	100 Year flood level (RL) pre-development	Existing flood risk rating
North of Puhinui Road near Noel Burnside Road (Point 5A)	277 Puhinui Road Site lvl RL 15.34 m	Building / house driveway	15.92 m	High risk Flood depth 0.58 m
Puhinui Road near Noel Burnside Road (Point 5B)	Puhinui Road 600 mm dia. pipe network Road lvl RL 15.54 m	Road corridor	15.92 m	High risk Flood depth 0.38 m
South of Puhinui Road near Noel Burnside Road (Point 5C)	Noel Burnside Road Road lvl RL 15.38 m	Road corridor	15.90 m	High risk Flood depth 0.52 m
Puhinui Road near Kenderdine Road (Point 6)	Puhinui Road Road lvl RL 17.79 m	Road corridor	17.95 m	Low risk Flood depth 0.15 m

7.3.1 Puhinui Road

At Puhinui Road near Noel Burnside Road (Location 5) the flow overtops the road at Point 5B with 0.38 m above existing road level for the 100 year ARI flood event. This results in a high flood risk rating.

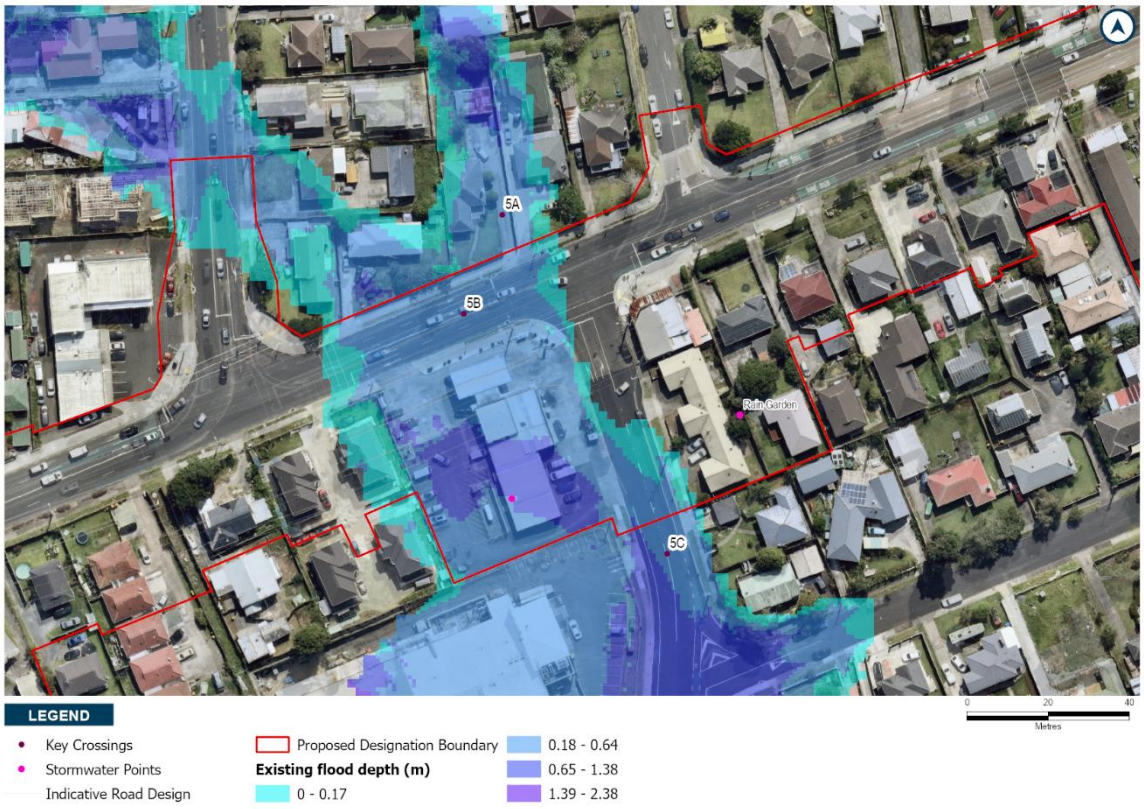


Figure 21: 100 year ARI event for the proposed NoR 3 corridor at Location 5

The existing flood issue at Location 5 includes residential and commercial development located within the flood plain. The flood modelling has found that at Point 5A there is predicted to be flood depths of up to 0.58 m in the 100 year ARI event which results in a high flood risk rating. At Point 5C there is predicted flood depths of 0.52 m on Noel Burnside Road in the 100 year ARI event which results in a high flood risk rating. Mitigation at this location is constrained by development either side of the proposed designation (see Section 7.4).

An initial desktop review has identified that floor levels appear to be approximately 0.6 – 0.7 m above ground level which indicates that insufficient freeboard is available. Raising the road would likely exacerbate the flood effects and it is recommended that the vertical alignment of the existing road is not changed. However, given the depth of the existing flooding, the road would also be impassable to most vehicles during a flood. As such, it is recommended that further investigation into temporary road diversions during a flood event should be undertaken.

7.4 Recommended measures to avoid, remedy or mitigate operational effects

A high existing flood risk is identified at Puhinui Road near Noel Burnside Road (Point 5C). Mitigation options at this location are limited due to development on either side of the proposed designation. Potential mitigation options at this location include:

- Keeping the current vertical alignment along Puhinui Road; and
- Investigating temporary road diversions or safe alternative routes during a flood event.

At Puhinui Road near Kenderdine Road (Point 6), the flood risk should not be exacerbated, potential mitigation at this location is to:

- Provide additional or upsized piped drainage and/or greater inlet capacity to reduce the risk of flooding.

It is recommended that the outcomes identified in Section 4.5 apply as a proposed condition on this NoR.

8 Airport to Botany Bus Rapid Transit – NoRs 4a and 4b

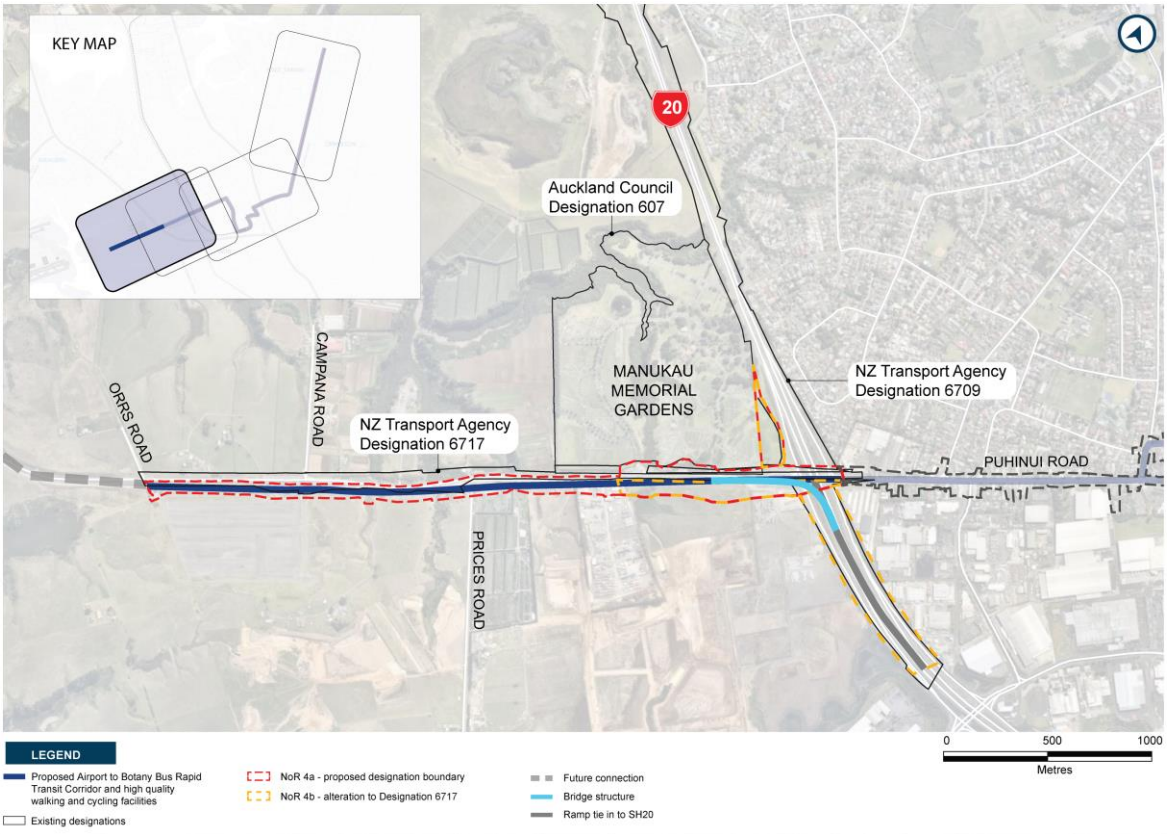
This section assesses specific flood matters relating to NoRs 4a and NoR 4b, the Project corridor between the SH20/20B Interchange and Orrs Road.

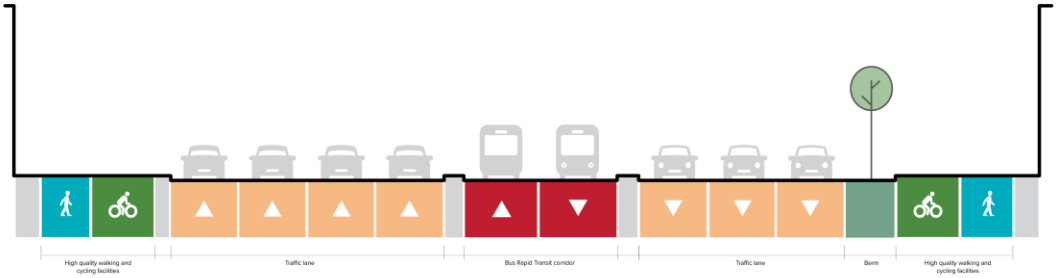
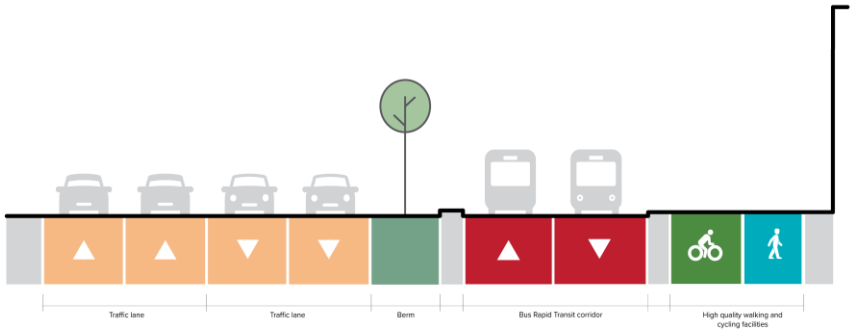
8.1 Project features and proposed works

As set out in Table 14 below, the proposed works in NoRs 4a and 4b include the widening of SH20B to accommodate a centre-running BRT corridor until the Manukau Memorial Gardens. From this point, the BRT corridor shifts south of SH20B until Orrs Road. Proposed works also include high quality walking and cycling facilities, eastbound lanes to Auckland Airport and a ramp from SH20B onto SH20 for southbound traffic.

There is an existing swale between the existing SH20B traffic lanes and the proposed BRT corridor and walking and cycling facilities. Linear treatment is proposed near the SH20/20B Interchange (in the NoR 3 area) and a piped connection would need to be provided.

Table 14: Overview of NoR 4a and 4b

NoRs 4a and 4b – SH20/20B Interchange to Orrs Road

Key features

BRT Corridor	• Centre-running on Puhinui Road through to the Manukau Memorial Gardens intersection (approx. 600 m west of SH20/20B Interchange); and • South running to Orrs Road.
Walking and cycling facilities	Walking and cycling facilities on southern side of the corridor
General traffic	• Two lanes in each direction; and • New southbound ramp from SH20B onto SH20.
Access	• Limited access; and • Access maintained via signals at Manukau Memorial Gardens and Campana Road.
Speed environment	60km/h
Signalised intersections	• SH20/SH20B Interchange; • Puhinui Road and Manukau Memorial Gardens; and • Puhinui Road and Campana Road.
Stormwater infrastructure	Swales
NoR 4b typical cross section	
	
NoR 4a typical cross section	
	

8.1.1 Stormwater catchment overview

NoRs 4a and 4b are within the Pūkaki Waokauri Creek catchment (see Section 3.5.2 for more detail). This section crosses three unnamed permanent streams by means of a bridge and two major culverts (see Table 15 for details).

8.1.2 Catchment characteristics

NoRs 4a and 4b are zoned under the AUP:OP as Future Urban Zone, Business – Light Industry Zone and Special Purpose – Cemetery Zone. The Manukau Memorial Gardens is within the NoRs 4a and 4b areas as well as some areas of residential and commercial land use on the eastern and western sides.

Currently stormwater runoff from SH20B is collected by either swales or catchpits and conveyed to outfalls via stormwater management devices. The swales and stormwater devices are within the existing NZ Transport Agency Designation 6717. All stormwater runoff from the existing carriageway is treated prior to discharging to the receiving environment.

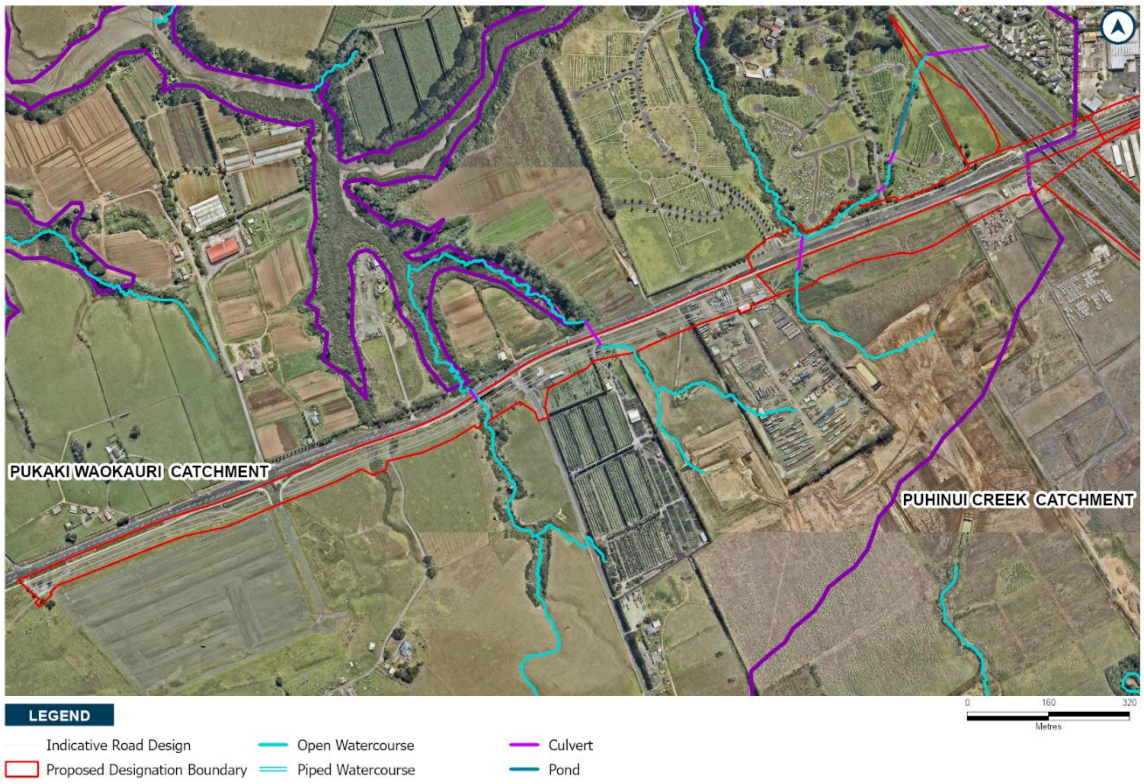


Figure 22: NoRs 4a and 4b in the context of the Pūkaki Waokauri Creek catchment

8.2 Assessment of construction effects and recommended measures to manage effects

Potential flooding effects during construction across the Project have been described in Section 4.2 above. Stream crossings are key sites for potential flooding effects during construction, NoRs 4a and 4b include the following stream crossings:

- Culvert crossing Puhinui Road near Manukau Memorial Gardens;
- Culvert crossing at 436 Puhinui Road; and

- Bridge duplication near Prices Road.

As set out in Section 4.3, the potential flooding effects during construction, including those associated with stream crossings will be managed through flood risk mitigation measures captured in the CEMP for existing high flood hazard areas.

8.3 Assessment of operational effects

This assessment of effects refers to the 100 year flood model results for the pre-development (existing) terrain and considers the flooding extents at the existing culvert / stream crossings. The flood effects identified in NoRs 4a and 4b are existing. This section of the corridor includes proposed widening to the south of SH20B which includes extending existing culverts and a bridge duplicated. While there may be changes to the vertical alignment, there is significant freeboard as existing flood levels downstream are several metres below the road levels. There may be an increase in culvert headwaters, however this can be managed by upsizing or duplicating culverts. No changes to existing flood levels are therefore expected.

The increase in impervious area is expected to be approximately 15% to 20%.

The corridor is close to the coast with no known habitable floors close to the stream crossings, indicating that flood attenuation is not required.

The corridor runoff is proposed to be treated by vegetated swales.

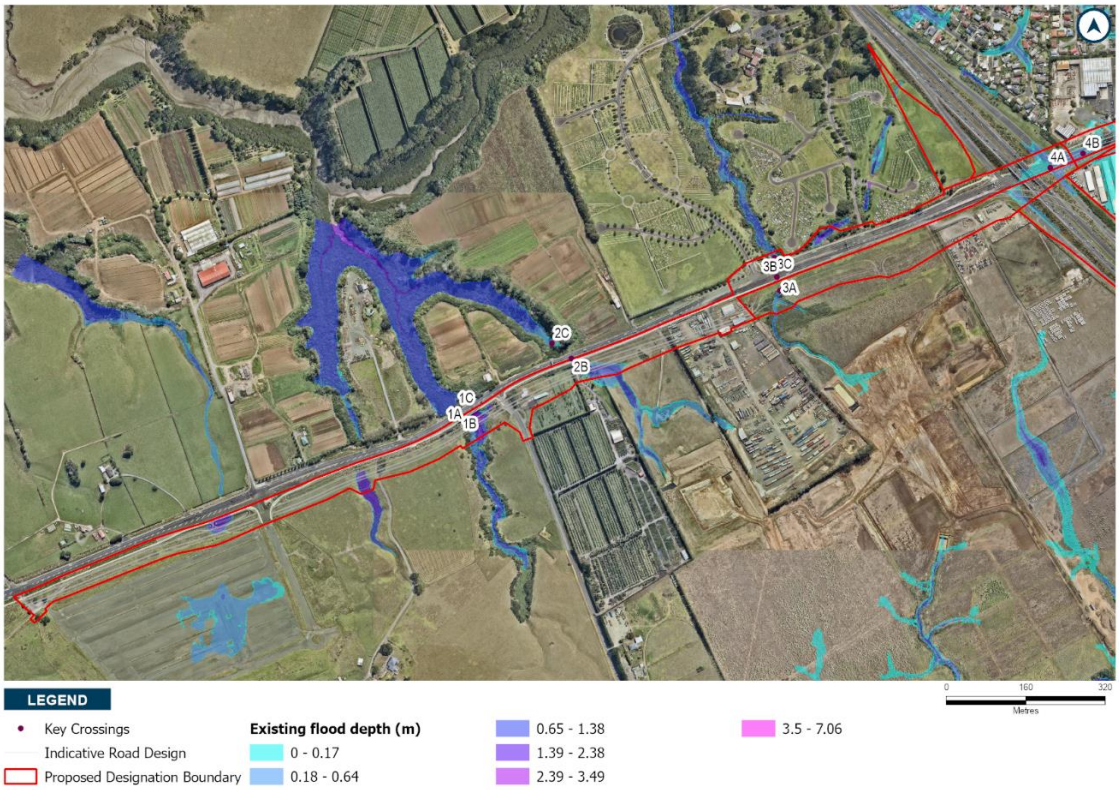


Figure 23: 100 year ARI event for the proposed NoR 4a and b corridor (Pūkaki Waokauri Creek Catchment)

The flood levels at the three major crossings identified above are below the road level and the road does not overtop. There is considered to be a negligible risk of flooding. At key crossings (bridge and culverts) adequate freeboard allowance is provided in accordance with NZTA Bridge Manual requirements.

At Locations 1, 2 and 3 the flood risk rating is negligible (see Table 15) and no further assessment has been undertaken. Locations where the flood risk is moderate has been discussed in more detail below.

Table 15: SH20B (NoRs 4a and 4b) existing flood levels at key locations

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	100 Year flood level (RL) pre-development	Existing flood risk rating
Waokauri Creek tributary crossing 1 (Points 1A and 1C) 2	Waokauri Creek Bridge Road lvl RL 9.28 m	Road corridor	2.76 m Upstream 2.54 m Downstream	Negligible risk Road does not overtop Adequate freeboard
Waokauri Creek tributary crossing 2 (Points 2A and 2C)	Culvert size unknown Road lvl RL 10.78 m	Road corridor	9.32 m Upstream 2.71 m Downstream	Negligible risk Road does not overtop Adequate freeboard
Waokauri Creek tributary crossing 3 (Points 3A and 3C)	Culvert size unknown Road lvl RL 16.06 m	Road corridor	Flood level: 12.17 m Upstream 9.55 m Downstream	Negligible risk Road does not overtop Adequate freeboard
SH20B/20 intersection 4A	Road lvl RL 19.71 m	Road corridor	19.86 m	Moderate risk Flood depth 0.16 m
East of SH20B/20 intersection 4B	Road lvl RL 19.61 m	Road corridor	19.85 m	Moderate risk Flood depth 0.24 m

8.3.1 SH20/20B Interchange

Near the SH20/20B Interchange (Points 4A and 4B) there is an existing moderate flood risk identified. The flood effect is likely to be related to the grading of the intersection and it is recommended that further consideration is given to identify the most appropriate way to effectively drain the road and prevent ponding at the detailed design stage.

[2] A to C: A is upstream water level, B is the existing road level, C is downstream water level

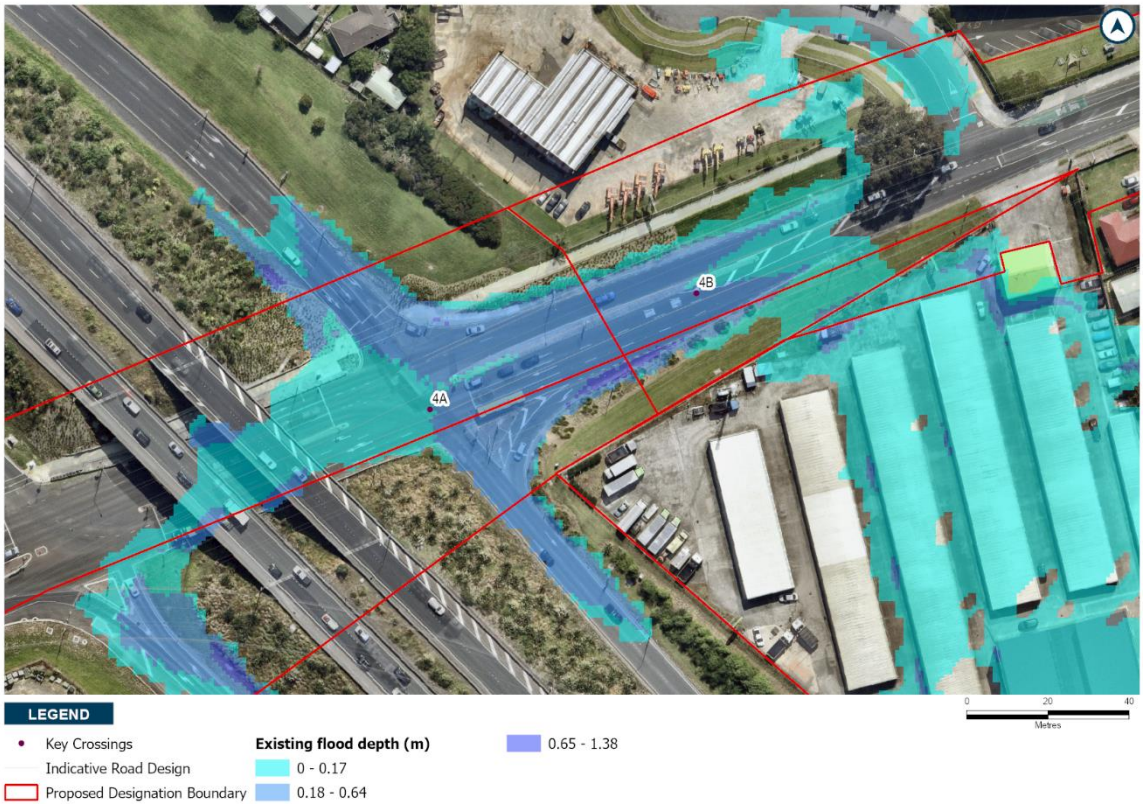


Figure 24: 100 year ARI event for the proposed NoRs 4a and 4b corridor at Location 4

8.4 Recommended measures to avoid, remedy or mitigate operational effects

Between Vision Place and the SH20/20B Interchange there is an existing moderate flood risk, proposed mitigation at this location includes:

- Keeping the current vertical alignment; and
- Providing additional piped drainage, greater inlet capacity or creating an overland flow path along the south side of the road.

It is recommended that the outcomes identified in Section 4.5 apply as a proposed condition on this NoR.

9 Sensitivity analysis

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given variance in a parameter. In this instance the sensitivity of road infrastructure to increased rainfall as a result of climate change has been considered.

As set out in Section 3.5 the flood model has allowed for two scenarios which involves two different climate change requirements. Results for a more severe climate change based on 3.8 degrees of warming have been compared to the result for 2.1 degrees of warming under the current Auckland Council Code of Practice.

In the future it is possible that there may be different requirements or additional RCPs which would need to be considered. However, at the time of writing this assessment, the sensitivity analysis has been prepared to understand the risk of climate change at the respective major crossings across the Project corridor.

9.1 NoR 1: Te Irirangi Drive section

The sensitivity analysis at the locations where a flood risk has been identified are shown in Table 16. The sensitivity analysis found that at point 18A there was >0.15 m increase in flood height under a more severe climate change scenario. This location is considered sensitive to climate change and additional consideration should be given to effects during higher rainfall events during the detailed design stage.

At point 20 there was also an increase in flood height, however there is sufficient freeboard at this location, and it is not considered sensitive to climate change.

Table 16: Consideration of flooding at major crossing identified for the Te Irirangi Drive Section (NoR 1)

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	2.1 degrees of warming 100 Year flood level (RL) pre-development	3.8 degrees of warming 100 Year flood level (RL) pre-development	Flood difference (m)	Revised freeboard (m)
Te Irirangi Drive near Smales Road (Point 18A)	2050 mm dia. pipe network Road lvl RL 20.89 m	Road corridor	21.88 m	22.05 m	+0.18 m	-1.16 m
18 Arkdeen Place (Point 18B)	Site lvl RL 22.09	House / building	22.18 m	22.31 m	+0.13 m	-0.22 m
Te Irirangi Drive near Kellaway Drive (Point 19A)	1350 mm dia. pipe network Road lvl RL 18.98	Road corridor	19.19 m	19.26 m	+0.08 m	-0.29 m
Te Irirangi Drive near Aaronville	Road lvl RL 18.96	Road corridor	19.44 m	19.48 m	+0.04 m	-0.52m

Way (Point 19B)						
Te Irirangi Drive near Brinlack Drive (Point 20B)	Road lvl RL 20.16 m	Road corridor	18.12 m Upstream 17.61 m Downstream	18.32 m 17.94 m	+0.19 m +0.33 m	+1.26 m +1.30 m

9.2 NoR 2: Manukau Central section

The sensitivity analysis at the locations where a flood risk has been identified are shown in Table 17. The sensitivity analysis found that there was there was a maximum increase of 0.14 m to the identified flood risk at locations within the NoR under a more severe climate change scenario (3.8 degrees of warming). Several locations are already experiencing flood effects and particularly points 7C, 9B, 9C and 10A are considered to be sensitive to climate change. Potential mitigation to address these effects is set out in Section 6. As the modelled flood level increase is minor no additional mitigation beyond that described in Section 6 is proposed. Mitigation for the existing flooding effect should consider sensitivity to climate change at the future detailed design stage.

Table 17: Consideration of flooding at major crossing identified for the Manukau Central Section (NoR 2)

Point	Existing Cross Drainage / Property address	Affected area/ vulnerability	2.1 degrees of warming 100 Year flood level (RL) pre-development	3.8 degrees of warming 100 Year flood level (RL) pre-development	Flood difference (m)	Revised freeboard (m)
135A Puhinui Road (Point 7A)	Site lvl RL 17.69 m	Building / house driveway	17.76 m	17.81 m	+0.05 m	-0.12
Puhinui Road near Bledisloe Street (Point 7B)	600 mm dia. pipe network Road lvl RL 17.58 m	Road corridor	17.68 m	17.78 m	+0.10 m	-0.21 m
142 Puhinui Road (Point 7C)	Site lvl RL 17.44 m	Building / house driveway	17.64 m	17.78 m	+0.14 m	-0.34 m
Cavendish Drive near Lambie Drive (Point 8)	Site lvl RL 19.68 m	Road corridor	19.77 m	19.77 m	0.00 m	-0.10 m
42 Lambie Drive (Point 9A)	Site lvl RL 17.58 m	Carpark	19.60 m	19.63 m	+0.03 m	-0.03 m
Lambie Drive near Cavendish	Road lvl RL 17.44 m	Road corridor	19.35 m	19.43 m	+0.09 m	-0.42 m

Drive (Point 9B)						
Cnr Lambie Drive and Cavendish Drive (Point 9C)	Cnr Lambie Drive and Cavendish Drive Road lvl RL 17.44 m	Carpark	19.34 m	19.43 m	+0.09 m	-0.74 m
Lambie Drive Ronwood Avenue Intersection (Point 10A)	Road RL 19.17 m	Road corridor	19.57 m	19.62 m	+0.05 m	-0.45 m
Hayman Park Near Lambie Drive carpark (Point 10B)	Site lvl RL 19.76 m	Open space / park	19.84 m	19.86 m	+0.01 m	-0.10 m
11 Ronwood Avenue (Point 11A)	Site lvl RL 24.06 m	Commercial building / carpark	24.08 m	24.10 m	+0.02 m	-0.04 m
2 Davies Avenue (Point 11C)	Site lvl RL 24.24 m	Carpark	24.45 m	24.48 m	+0.03 m	-0.24 m

9.3 NoR 3: Puhinui section

The sensitivity analysis at the locations where a flood risk has been identified are shown in Table 18. The sensitivity analysis found that there was a maximum increase of 0.11 m to the identified flood risk at locations within the NoR under a more severe climate change scenario (3.8 degrees of warming). However, at these locations there is no freeboard and hence they can be considered sensitive to flood effects. Potential mitigation to address these effects is set out in Section 7. As the modelled flood level increase is minor no additional mitigation beyond that described in Section 7 is proposed. Mitigation for the existing flooding effect should consider sensitivity to climate change at the future detailed design stage.

Table 18: Consideration of flooding at major crossing identified for the Puhinui Section (NoR 3)

Point	**Existing Cross Drainage / Property address**	**Affected area/ vulnerability**	**2.1 degrees of warming 100 Year flood level (RL) pre-development**	**3.8 degrees of warming 100 Year flood level (RL) pre-development**	**Flood difference (m)**	**Revised freeboard (m)**
North of Puhinui Road near Noel Burnside	277 Puhinui Road Site lvl RL 15.34 m	Building / house driveway	15.92 m	16.03 m	+0.11 m	-0.69 m

Road (Point 5A)						
Puhinui Road near Noel Burnside Road (Point 5B)	Puhinui Road 600 mm dia. pipe network Road lvl RL 15.54 m	Road corridor	15.92 m	16.03 m	+0.11 m	-0.49 m
South of Puhinui Road near Noel Burnside Road (Point 5C)	Noel Burnside Road Road lvl RL 15.38 m	Road corridor	15.90 m	16.01 m	+0.11 m	-0.62 m
Puhinui Road near Kenderdine Road (Point 6)	Puhinui Road Road lvl RL 17.79 m	Road corridor	17.95 m	17.97 m	+0.02 m	-0.17 m

9.4 NoRs 4a and 4b: SH20B section

The sensitivity analysis at the locations where a flood risk has been identified are shown in Table 19. The sensitivity analysis found that at Locations 2 and 3 there was >0.4 m increase in flood depth under a more severe climate change scenario. However, there is sufficient freeboard even under a more severe climate change scenario and these locations are not considered sensitive to climate change. Future culvert upgrades to prevent upstream ponding should consider sensitivity to climate change.

Table 19: Consideration of flooding at major crossing identified for the SH20B Section (NoRs 4a and 4b)

Point	**Existing Cross Drainage / Property address**	**Affected area/ vulnerability**	**2.1 degrees of warming 100 Year flood level (RL) pre-development**	**3.8 degrees of warming 100 Year flood level (RL) pre-development**	**Flood difference (m)**	**Revised freeboard (m)**
Waokauri Creek tributary crossing 1 (Points 1A and 1C) [3]	Waokauri Creek Bridge Road lvl RL 9.28 m	Road corridor	2.76 m Upstream 2.54 m Downstream	2.90 m 2.58 m	+0.14 m +0.05 m	+6.38 m
Waokauri Creek tributary crossing 2 (Points 2A and 2C)	Culvert size unknown Road lvl RL 10.78 m	Road corridor	9.32 m Upstream 2.71 m Downstream	9.78 m 2.73 m	+0.46 m +0.02 m	+1.46 m

[3] A to C: A is upstream water level, B is the existing road level, C is downstream water level

Waokauri Creek tributary crossing 3 (Points 3A and 3C)	Culvert size unknown Road lvl RL 16.06 m	Road corridor	Flood level: 12.17 m Upstream 9.55 m Downstream	12.59 m 9.62 m	+0.43 m +0.06 m	+3.47 m
SH20B/20 intersection 4A	Road lvl RL 19.71 m	Road corridor	19.86 m	19.89 m	+0.03 m	+0.18 m
East of SH20B/20 intersection 4B	Road lvl RL 19.61 m	Road corridor	19.85 m	19.88 m	+0.03 m	+0.12 m

10 Conclusions

This assessment has considered the potential flood effects of the Project. The assessment uses a flood risk rating to identify those areas where existing flood effects are likely and makes recommendations to mitigate any effects during the future detailed design stage of the Project.

The assessment found that there is unlikely to be significant additional risk of flood effects during construction. Proposed works will be located outside of flood plains and overland flow paths as far as practicable. Where this is not possible, potential flooding effects will be managed through the flood risk mitigation measures set out in the CEMP for existing high flood hazard areas. For those areas where there is an increased flood risk, mitigation measures such as carrying out construction works during dry weather and using diversion drains will be adequate to manage this risk and will be identified through the CEMP.

There are potential operational effects risks of increased flood levels upstream and downstream of crossings and where the vertical alignment of the road is elevated. Some of the effects were assessed as moderate based on a flood depth of greater than 0.15 m for more vulnerable uses (e.g. habitable buildings) and 0.5 m for less vulnerable uses (e.g. open space).

A number of potential management and mitigation measures have been provided to manage operational effects at the future detailed design stage. However, this corridor is heavily constrained by existing residential and commercial development within flood plains and flood prone areas. In some locations the recommendation is to maintain the current vertical alignment, this means the road will overtop however flood effects will not increase.

A series of outcomes are identified to be included as conditions on the NoRs and maintain effects at a level that is no more than minor.

The increase in corridor impervious area associated with urban areas is between 5 and 15%. In the Pakuranga Creek catchment no attenuation is expected, and flows would be passed forward. In other catchments, attenuation can be incorporated into treatment devices or included into storage areas adjacent to the corridor. Alternatively, network improvements could reduce flooding in some places if an integrated flood management approach with other organisations is adopted.

The potential mitigation measures of the flood assessment are set out in the table below. These are provided as potential mitigation measures to be considered by the future designer of how existing and potential effects could be mitigated.

NoR	Location	Flood Risk Rating	Recommendation
NoR 1	Te Irirangi Drive near Bishop Dunn Place	Negligible	• n/a
	Te Irirangi Drive south of Smales Road	High	• Lower the intersection to allow flood water to move from trapped low point • Investigate additional pipe capacity and inlets • No flood flow attenuation for increased impervious area as the existing road corridor is in

			the lower half of the catchment
	Te Irirangi Drive north of Smales Road	Moderate	• Provide additional or upsized piped drainage and/or greater inlet capacity • No flood flow attenuation for increased impervious area as the existing road corridor is in the lower half of the catchment
NoR 2	Te Irirangi Drive near Diorella Drive / Boundary Road	Low to negligible	• No flood flow attenuation for increased impervious area for sub-catchment to the existing Rongomai attenuation pond • Flood flow attenuation for increased impervious areas within the proposed raingardens (if required) for sub-catchment to Ōtara Creek
	Lambie Drive / Cavendish Drive	High	• Keep the current vertical alignment • Flood flow attenuation for increased impervious areas within proposed linear treatment
	Davies Avenue / Ronwood Avenue	Moderate - High	• Reduce the level of Davies Avenue to allow overland flow to discharge into Hayman Park • Provide additional pipe capacity or diversion drains parallel to the road • Flood flow attenuation for increased impervious areas within the proposed wetland at Hayman Park
	Puhinui Road near Cavendish Drive	High	• Keep the current vertical alignment • Flood flow attenuation for increased impervious areas within the proposed designation boundary (if required)
NoR 3	Puhinui Road near Noel Burnside Road	High	• Keep the current vertical alignment • Flood flow attenuation for increased impervious areas within the proposed

			designation boundary (if required)
NoRs 4a and 4b	Puhinui Road between Vision Place and the SH20/20B Interchange	Moderate	• No flood flow attenuation for increased impervious area • Increase culvert capacity if required

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 proposed mitigation that are described in the report.