TE TUPU NGĀTAHI
SUPPORTING GROWTH

Drury Arterial Network Assessment of Flooding Effects

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WAKA KOTAHI NZ TRANSPORT AGENCY

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Table 1: Glossary of technical terms / acronyms

Acronym	Term
AEE	Assessment of Effects on the Environment
AC	Auckland Council
ARI	Average Recurrence Interval
AT	Auckland Transport
AUPOIP	Auckland Unitary Plan Operative in Part
CC	Climate Change
CEMP	Construction Environmental Management Plan
FTN	Frequent Transit Network
FUZ	Future Urban Zone
GIS	Geographical Information System
MPD	Maximum Probable Development
NIMT	North Island Main Trunk
NoR	Notice of Requirement (under the Resource Management Act 1991)
NZUP	New Zealand Upgrade Programme
SH1	State Highway 1
SH22	State Highway 22
Waka Kotahi	Waka Kotahi NZ Transport Agency

Table 2: Glossary of defined terms

Term	Meaning
Auckland Council	Means the Unitary Authority for the Auckland Region.
Average Recurrence Interval (ARI)	Average period of time between rainfall events or flow rates which exceed a certain magnitude.
Catchment	An area of land draining by force of gravity into a stream or watercourse at a given location.
Climate Change	Climate change resulting from global warming due to greenhouse gas emissions.
Drury Package	Five Notices of Requirement for the Drury Arterial Network for Auckland Transport and Waka Kotahi NZ Transport Agency.
Flood plain	The plan extent of flooding in a given ARI rainfall event.
Freeboard	Design margin to allow for factors omitted or uncertain in the overall design (e.g. uncertainties in flood level estimation, wave action, localised water level variations).

Term	Meaning
Maximum probable development	Design case for consideration of future flows allowing for development within a catchment that takes into account the maximum impervious surface limits of the current zone or, if the land is zoned Future Urban in the Auckland Unitary Plan, the probable level of development arising from zone changes.
Overland flow	Stormwater runoff travelling downhill over the surface of the ground along the path of least resistance towards streams and watercourses or the sea.
Pre-project development	Existing site condition prior to the project (including existing buildings and roadways)
Post-project development	Site condition after the project has been completed (including existing and new buildings and roadways)

2 Executive Summary

Assessment undertaken

This report provides an assessment of flood hazard effects associated with the construction, operation and maintenance of the Projects that comprise the Drury Arterial Network (Drury Package). The Projects are shown on Figure 3-1.

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

In the context of this assessment, flood hazard effects may include changes to; the flood freeboard to habitable buildings, overland flow paths, the ability to access property by residents and emergency vehicles, the depth of flooding to roads and flooding arising from the blockage of stormwater drainage. The effects considered relate to existing habitable buildings / infrastructure and potential future effects on upstream and downstream properties.

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

- Desktop assessment to identify potential flooding locations from Auckland Council flood plains on Geomaps
- Site visits with the project team and Council
- Flood modelling of the pre-project development and post-project development terrain – both with Maximum Probable Development (MPD) with 100 year Average Recurrence Interval (ARI) plus climate change (CC) rainfall
- Flood depth maps were produced for the pre-project development and post-project development terrain and flood difference maps were produced to show the change in flood levels and extents (greater than 50mm) as a result of the Projects
- Inspection and review of flood difference maps. At key cross drainage locations such as bridges and where there are noticeable changes in flood extents or flood levels, consideration was given to flood hazard issues
- Additional site visits to those locations that were identified as having potential flooding effects arising from the projects– i.e. viewing the extent of estimated flooding and its potential effect on buildings, considering property access effects and potential increases to flow velocity/depth

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

Results of assessment and recommended measures

Notice of Requirement D1

Under the Auckland Unitary Plan, the NoR D1 project area is zoned as Future Urban, except at the Ngakoroa Reserve which is zoned Open Space. The Future Urban zoned land is currently comprised of mostly rural or rural residential properties.

The NoR contains an existing bridge at Ngakoroa Stream which already overtops on the western approach during the 100 year ARI rainfall event.

Construction phase effects

There may be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridge. However, the details of the construction approach will be confirmed at detailed design. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

Operational phase effects

The operational phase flooding effects of NoR D1 have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development terrain) flood model results.

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes and conditions outlined in this report.

The operational flood hazard effect of the Project is positive at the Ngakoroa Stream due to the greater conveyance capacity of the new Ngakoroa Stream Bridge. Operationally, this results in much improved freeboard to the bridge (with benefits to the safe passage of flow and safety of those using the bridge). There is an existing (and potential future) adverse effect with an increased depth of flooding over SH22 near Burberry Road. Design refinements and/or matters that need to be addressed further at detailed design to address this adverse effect have been identified. There is space within the designation sought for the works required for stormwater and flood mitigation.

Notice of Requirement D2

Under the Auckland Unitary Plan, the NoR D2 project area is zoned as Future Urban, except; around Bremner Road west of SH1, which is zoned Residential and Town Centre; between the NIMT railway and State Highway 1 which is zoned Business, and at the Drury Sports Centre which is zoned Open Space.

The residential zoned land around Bremner Road is undergoing development as part of the Auranga development.

The Future Urban zoned land is currently comprised of mostly rural or rural residential properties. Land south of Waihoehoe Road is identified for the Drury Central Rail Station and is the subject of a Plan Change Application by Kiwi Properties.

The NoR extent contains existing bridges over the Ngakoroa and Hingaia Streams which already overtop during the 100 year ARI rainfall event. There are also existing flooding issues near residential buildings on Jesmond Road and commercial buildings on Norrie Road.

Construction phase effects

There may be some temporary construction phase flooding risk primarily associated with temporary staging platforms required for new bridges and the construction of culverts on line. However, the details of the construction approach will be confirmed at detailed design. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

Operational phase effects

The operational phase flooding effects of NoR D2 have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development terrain) flood model results.

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes and conditions outlined in this Report. Specific design considerations to manage potential flooding effects should be considered in the following areas of the Project alignment.

The Jesmond Road FTN Upgrade could increase operational phase flood levels and create flood prone areas upstream of the sag points where overland flow crosses the transport corridor. This could have effects on future urban development upstream. With careful design of road levels, upsizing of culverts and providing inlet protection, flood levels can be appropriately managed to pre-Project levels. Construction of a diversion drain at 119, 125 and 131 Jesmond Road will direct overland flow away from the buildings on site, lower flood levels and could improve the existing situation. Conditions on the proposed designation identify key outcomes to be achieved (that will address the above matters) at detailed design.

There is a potential increase in flood levels greater than 0.5m and creation of a flood prone area if a culvert was used for a stream crossing of the proposed transport corridor at chainage 600 on Bremner Road. As the upstream catchment is 115 ha (generating large flows) and a culvert alternative would be long and large (with consequent ecological effects), a bridge is recommended at this location. A stream diversion is likely required on the upstream side to keep the bridge length to a single span.

The existing Bremner Road Bridge over the Ngakoroa Stream is proposed to be replaced as part of the SH 1 widening works for the Waka Kotahi Papakura to Drury South project (NZUP Project). In the future, when Bremner Road is upgraded as part of the Jesmond to Waihoehoe Road West FTN Upgrade, the existing bridge will either be widened or a new bridge constructed alongside it to provide two additional lanes. However, existing Transpower overhead 220kv lines limit how much the vertical

alignment of the bridges can be raised to address flood risk events. The future bridge will be higher than the existing one and have improved flood resilience with less frequent overtopping on the western approach and have a smaller part of the bridge support structure submerged. Flood flow velocity is relatively low at the bridge and by using a span of 40m for the bridge there will be a 160 mm drop in flood levels upstream during the 100 year ARI rainfall event.

The replacement of the Hingaia Stream Bridge will give a reduction in upstream flooding during the 100 year ARI rainfall event of 320 mm at Norrie Road. The existing Norrie Road/Hingaia Stream Bridge is set below the 100 year flood levels and increases upstream flood levels. The proposed new bridge is higher with longer spans, which will provide greater flood freeboard to the corridor and improve resilience.

It is recommended that the designation include a condition requiring the existing Norrie Road Bridge be fully removed, once the construction phase is over and the new bridge over Hingaia Stream is operational, so that the reduction in upstream flooding is realised. The Bremner Road/Firth St intersection is subject to flooding in both pre and post development scenarios for the 10 and 100 year ARI rainfall events. No new mitigation measures are required. Temporary, infrequent road closure may be required during these events, as it is in the pre-development scenario.

Flooding effects from the Waihoehoe Road West section of the corridor are considered no more than minor as the road is located on a gentle ridge and does not encroach on to any flood plains or overland flow paths.

The overall effect of NoR D2 on flooding is positive or can be adequately mitigated within the designation assuming the recommendations above are implemented. Other design refinements and/or matters that need to be addressed further at detailed design have been identified in this Report.

Notice of Requirement D3

Under the Auckland Unitary Plan, the land that comprises the NoR D3 project area is zoned as Future Urban. The Future Urban zoned land is currently comprised of mostly rural or rural residential properties.

Construction phase effects

There may be some temporary construction phase flooding risk associated with temporary works required for the construction of culverts and stormwater management infrastructure.

However, the details of the construction approach will be confirmed at detailed design. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

Operational phase effects

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes and conditions outlined in this report.

Stormwater management infrastructure is proposed to discharge overland flow paths or be connected to future drainage systems developed as part of future land development. These will be decided at detailed design. There is land available within the proposed designation for the stormwater management infrastructure required to manage these potential effects.

Notice of Requirement D4

Under the Auckland Unitary Plan, the land that comprises the NoR D4 project area is zoned as Future Urban, except:

- adjacent to Hunua Road which is zoned Business and
- near the Hunua and Waihoehoe Streams which is zoned Open Space

The Future Urban zoned land is currently comprised of mostly rural or rural residential properties.

NoR D4 will require new bridge crossings of the Waipokapū and Waihoehoe Streams.

There are existing houses within the flood plain on Harry Dodd Road.

Construction phase effects

There may be some temporary construction phase flooding risk associated with temporary works required for new bridges and the construction of culverts on line. However, the details of the construction approach will be confirmed at detailed design. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

Operational phase effects

The operational phase flooding effects of NoR D4 have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development terrain) flood model results.

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes and conditions outlined in this report.

The majority of land upstream of the corridor is zoned future urban and therefore, depending upon the timing of the construction of the corridor and potential upstream development, there could be operational effects on either the existing dwellings (at Walker Road and Harry Dodd Road) or the potential upstream development.

In terms of existing properties, there are potential increases in flood levels identified for properties at 105 Walker Road and Harry Dodd Road. The flooding at 105 Walker Road can be mitigated by an overland flow path to be constructed within the designation. Within 125m upstream of the proposed Waihoehoe Stream Bridge the flood difference maps show that there is less than 50mm of change, with existing properties at Harry Dodd Road identified as experiencing up to a 30mm increase in flood levels. We consider that the increase of less than 50mm shows that the proposed bridge and

approaches over the Waihoehoe Stream can be constructed within an acceptable level of effects. However, it is anticipated that up to five existing dwellings may have freeboard less than 500mm and, if this is confirmed, further optimisation of the bridge arrangement or some local mitigation may be required. It is recommended that the magnitude of the effect is confirmed at the detailed design phase and, for any existing authorised habitable floors experiencing more than a 10% reduction in freeboard, mitigation is provided so that there is no more than a 10% reduction in freeboard.

In terms of potential upstream development within the future urban zone, the corridor construction introduces two operational flooding effects; changes in upstream flood levels - thereby affecting the level at which future habitable floor levels are set, and the creation of flood prone land. If development of the Future Urban zoned land within the floodplain is to be realised it is expected that habitable buildings would not be allowed within the current floodplain extents, earthworks within/adjacent the flood plain would be undertaken to form development sites and building floor levels would be constructed above the existing floodplain with appropriate freeboard. Given the degree of earthworks change in the catchment and the modelled minor changes in flood levels, it expected that the predicted changes in flood levels identified can be easily accommodated. The flood prone issue relates to the corridor embankment forming an upstream pond in some areas (chainages 1400, 2500 to 2700 and 3000 to 3700) if the capacity of cross drainage is blocked or overwhelmed. This can be avoided by setting habitable floor levels above the level of the completed road or mitigated by upsizing culverts and providing inlet protection/secondary inlets/overland flow paths (for which there is space within the proposed designation). In both of these operational flooding cases, it is recommended that coordination occur with Auckland Council and adjacent property owners/developers to address these issues through detailed design of the Project and upstream development design processes.

Most of the land identified for future stormwater management wetlands is outside flood plains. Wetlands 3 and 4 are constrained and have had to be placed downstream of the bridge in the edge of floodplains in low water velocity areas. This is considered low risk with further assessment of the risk of scour and overtopping and mitigation recommended for the detailed design phase.

Overall, it is considered that the potential flooding effects arising from the proposed transport corridor for NoR D4 can be adequately mitigated and that there is land available within the proposed designation to provide for the required works.

Notice of Requirement D5

Under the Auckland Unitary Plan, the land that comprises the NoR D5 project area east of the Ōpāheke Road Bridge is zoned as Future Urban, except near the Ōtūwairoa Stream and the Drury Reserve which is zoned Open Space. West of the Ōpāheke Road Bridge is zoned mostly Residential with a small amount of Future Urban. The Future Urban zoned land is currently comprised of mostly rural or rural residential properties.

The NoR contains an existing bridge over the Ōtūwairoa Stream at Ōpāheke Road and an existing crossing of the Mangapū Stream at Ponga Road via twin 2000mm dia. culverts.

Construction phase effects

There may be some temporary construction phase flooding risk associated with temporary works required for new bridges and the construction of culverts on line. However, the details of the

construction approach will be confirmed at detailed design. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

Operational phase effects

The operational phase flooding effects of NoR D5 have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development terrain) flood model results.

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes outlined in this Report. Specific design considerations to manage potential flooding effects should be considered in the following areas of the Project alignment.

The new bridge over the Mangapū Stream is higher than the existing road which will improve the corridor's resilience to flooding. The span and the design of the bridge needs to be developed further to not increase flood levels upstream.

The proposed cycle and pedestrian bridges at Ōpāheke Road over the Ōtūwairoa Stream could increase flood levels upstream, including at a house at 156 Ōpāheke Road. It is recommended that the magnitude of the effect is confirmed at the detailed design phase and, for existing authorised habitable floors with more than a 10% reduction in freeboard, mitigation is provided so that there is no more than a 10% reduction in freeboard. Mitigation could consist of increasing the span of the existing bridge to achieve freeboard. Any other new or redeveloped habitable floors upstream should be designed to account for the post development scenario. However, it is recommended there is 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. A management response is recommended to be developed to manage use of the Ōtūwairoa Stream bridges during overtopping flooding events.

Most of the land identified for future stormwater management wetlands is outside flood plains. Ōpāheke wetland 1 is an upgrade of an existing Auckland Council pond on the edge of the floodplain. This is considered low risk with further assessment of the risk of scour and overtopping and mitigation recommended for the detailed design phase.

Overall, it is considered that the potential flooding effects arising from the proposed transport corridor for NoR D5 can be adequately mitigated and that there is land available within the designation sought to provide for the required works.

3 Introduction

This report has been prepared for the Drury Arterial Network Notices of Requirement (NoRs) for Auckland Transport (AT) and Waka Kotahi NZ Transport Agency (Waka Kotahi) (the "Drury Package"). The NoRs are to designate land for future strategic transport corridors as part of the Supporting Growth Programme to enable the future construction, operation and maintenance of transport infrastructure in the Drury-Ōpāheke area of Auckland.

The Auckland Council Drury-Ōpāheke structure plan area is expected to grow over the next 30 years and is estimated to provide about 22,000 houses and about 12,000 jobs with a population of about 60,000. The Drury Package will provide route protection for the local arterials, which include walking, cycling and public transport (including the Frequent Transit Network (FTN)), needed to support the expected growth in Drury. This report assesses the flood hazard effects of the proposed Projects, that together comprise the Drury Package, as shown in Figure 3-1.

Table 3-1 Drury Package: Notices of Requirement and Projects

Notice	Project
NoR D1	Alteration to NZ Transport Agency designation 6707 - State Highway 22 (SH22) Upgrade
NoR D2	Jesmond to Waihoehoe West FTN Upgrade
NoR D3	Waihoehoe Road East Upgrade
NoR D4	Ōpāheke North-South FTN Arterial
NoR D5	Ponga Road and Ōpāheke Road Upgrade

The Drury Package has been developed through an alternatives assessment. Transport corridor alternatives and route refinements were assessed by a multi-disciplinary team against a programme wide Multi-Criteria Assessment. This assessment phase was completed in February 2020, and further design changes have been adopted through the Assessment of Environmental Effects (AEE) process for the Drury Package, in response to a range of construction and environmental considerations.

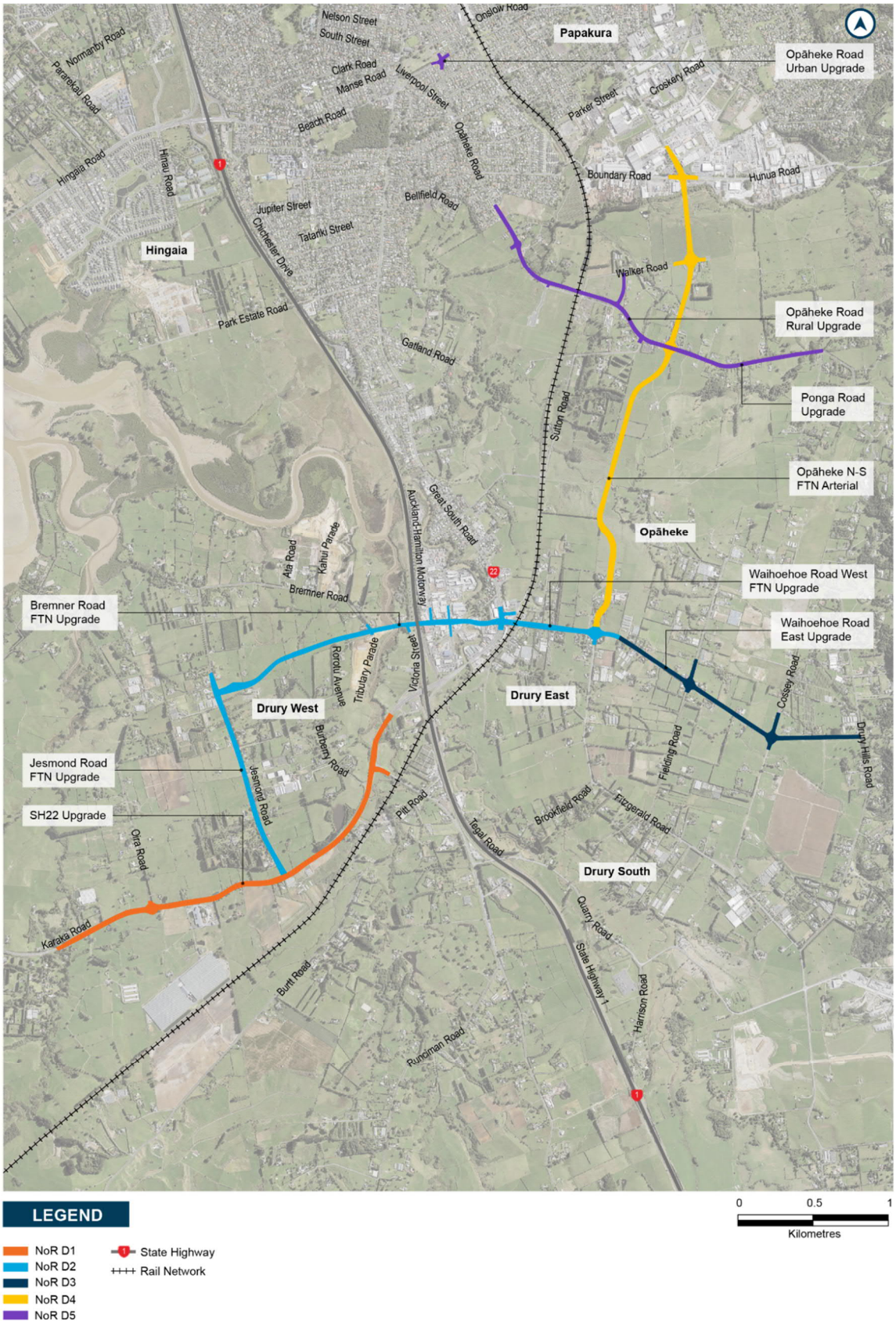


Figure 3-1: Drury Package Projects and Notices of Requirement

3.1 Background

Auckland is New Zealand's largest city, home to approximately 1.65 million people. In 2017, Auckland attracted 36,800 new residents; more than the rest of the country combined. The Auckland Plan 2050 – Development Strategy signals that Auckland could grow by 720,000 people to reach 2.4 million over the next 30 years. This will generate demand for more than 400,000 additional homes and require land for 270,000 more jobs.[1] Most of this growth will go into existing urban areas. However, around a third will go into future urban zone (FUZ) as identified in the Auckland Unitary Plan: Operative in Part (AUPOIP). The FUZ areas are "greenfields", that is, generally rural land identified to be urbanised over time.

The Supporting Growth Programme is a collaboration between AT and Waka Kotahi to plan transport investment in Auckland's future urban zoned areas over the next 10 to 30 years. AT and Waka Kotahi have partnered with Auckland Council, Manawhenua and KiwiRail Holdings Limited (KiwiRail) and are working closely with stakeholders and the community to develop the strategic transport network to support Auckland's growth areas.

The key objective of the Supporting Growth Programme is to protect land for future implementation of the required strategic transport corridors/infrastructure. As a form of route protection, designations will identify and appropriately protect the land necessary to enable the future construction, operation and maintenance of these required transport corridors/infrastructure. A designation is important as it provides certainty for the Requiring Authority that it can implement the work. It also provides property owners, businesses and the community with increased certainty regarding future infrastructure, so they can make informed decisions (if confirmed it will be identified in the AUPOIP). It can also significantly reduce long-term costs for local and central government and enable more effective land use and transport outcomes.

3.2 Drury Package

The Drury Package proposes an arterial network to support the expected future growth in Drury-Ōpāheke. The Drury Package comprises five separate projects which together form the Drury Arterial Network. The network includes provision for general traffic, walking and cycling, and frequent public transport. Overall, the Drury Package aims to improve connectivity within and through the Drury-Ōpāheke area, providing high quality, safe and attractive transport environments. Each Project within the Drury Package will be designated separately as follows:

- **NoR D1:** Alteration to Waka Kotahi NZ Transport Agency designation 6707 - State Highway 22 (SH22) Upgrade
- **NoR D2:** Jesmond to Waihoehoe West FTN Upgrade
- **NoR D3:** Waihoehoe Road East Upgrade
- **NoR D4:** Ōpāheke North-South FTN Arterial (Ōpāheke N-S FTN Arterial)
- **NoR D5:** Ponga Road and Ōpāheke Road Upgrade

[1] Draft Auckland Plan 2050 Development Strategy: https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/auckland-plan/development-strategy/future-auckland/Pages/what-auckland-look-like-future.aspx

3.3 Purpose and Scope of this Report

This report provides an assessment of flood hazard effects associated with the construction, operation and maintenance of the Drury Package. This assessment has been prepared to inform the AEE for the NoRs.

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

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 as they are the only matters that would trigger a District Plan consent requirement under the AUPOIP. Where regional plan consenting requirements are triggered, these will not be authorised by the designation, and will require further regional consents.

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 form of the works required for the Drury Package could lead to risks associated with flooding as a natural hazard and provide an assessment of effects to demonstrate that these risks are minor and can be appropriately managed in the future.

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

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

The design philosophy and methods used for sizing stormwater management works are set out in the design report. Some key assumptions that were used to identify the amount of land sought for stormwater management works within the designation include the following:

- Wetlands are sized to attenuate 100 year peak flows from the corridor (as of the required stormwater wetland sizing criteria this gives the largest footprint). Quality and retention/detention requirements are able to fit within the footprint
- Allowance is made for wetland attenuation storage and hydraulic gradients from corridor inlet to discharge point (typically a minimum of 2.0 to 2.5m vertically)

- Wetland geometry and footprints were modelled to determine the required cut and fill and a 15m buffer added for construction purposes and maintenance access
- A minimum 6m buffer is provided around the corridor earthworks extents to provide space for construction purposes and allow for works such as drainage channels and culvert inlets/outlets and flexibility in the vertical alignment
- Diversion channels are identified where they are needed to prevent upstream flooding

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

Earthworks for development within the FUZ upstream of the corridors will change catchment hydrology, the terrain and building and property types that are potentially exposed to flooding. The assessment has therefore considered specific effects on existing properties and more generally considered effects on potential future development. It is expected that coordination and integration of the corridor design with FUZ development will be required to confirm and address potential future effects.

The purpose of this report is to:

- Identify and describe the existing and likely future environment that is potentially affected by flooding
- Identify and describe the actual and potential flooding effects of the Projects
- Recommend measures as appropriate to avoid, remedy or mitigate potential adverse flooding effects (including any conditions required)
- Present an overall conclusion of the level of potential adverse flooding effects of each of the Projects after recommended measures are implemented.

The key matters addressed in this report are as follows:

- Description of the Projects as they relate to stormwater
- Overview of the methodology used to undertake the assessment and identification of the assessment criteria and any relevant standards or guidelines
- Identification and description of the existing and likely future environment
- Description of the actual and potential positive flooding effects of each project
- Description of the actual and potential adverse flooding effects during the construction of each project
- Description of the actual and potential adverse flooding effects during the operation of each project
- Recommended measures to avoid, remedy or mitigate potential adverse flooding effects (including any conditions/management plan required)
- Overall conclusion of the level of potential adverse flooding effects of each of the projects after recommended measures are implemented

3.4 Report Structure

This report is structured to reflect the key matters listed above in Section3.3.

In order to provide a clear assessment of each project, descriptions and assessments have been separated to reflect each of the notices sought.

3.5 Preparation for this Report

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

In conjunction with a desktop study, a site visit was undertaken with the project team and Auckland Council specialists to obtain an overview of the surrounding environment.

The Ōpāheke-Drury Structure Plan and AUPOIP were used to identify the existing and future likely environment.

Information from the project team and Auckland Council catchment models for Ōtūwairoa, Hingaia and Ngakoroa Streams were used to assess the relative changes to flooding depths and extents between the existing (pre-project development) and future (post-project development) terrain. Further site visits have been undertaken following modelling to help identify possible causes and effects, and in some cases, mitigation measures.

4 Assessment Methodology

Chapter Summary

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

- Desktop assessment to identify potential flooding locations, namely:
    - Using the AC and SGA GIS to identify where existing buildings appear to be near/within the existing flood plains.
    - Using the AC and SGA GIS to identify where the Projects involve work near stream crossings/major overland flow paths.
- Site visits with project team and Council
- Flood modelling of the pre-project development and post-project development terrain
    - Flood modelling of the existing terrain and proposed SGA terrain – both using MPD development with 10 and 100 year ARI plus CC rainfall.

      Model results are used to identify changes in 10 and 100 year MPD flood levels to create flood difference maps.
- Inspection of the maps to identify flooding effects. At key cross drainage locations such as bridges and where there are noticeable changes in flood extents or flood levels, consideration was given to flood hazard issues.
- Subsequent site visits to those sites that were identified as having potential flooding effects from the projects. This included viewing the extent of estimated flooding and potential effects on buildings and considering property access effects and potential increases to flow velocity/depth.

4.1 Desktop Assessment

A desktop study was carried out to assess the flood hazards during construction and operation for each project and identify at risk locations for assessment while flood modelling was underway.

To inform the assessment, areas where existing buildings appeared to be near/within the existing flood plains were identified. These areas are considered potentially sensitive to flooding effects. In addition, areas where the Projects are carrying out significant work near the stream crossings/major overland flow paths that may alter the existing flood plains, ponding volumes, and natural drainage paths were considered potentially sensitive. Ten sites were identified using these criteria and are summarized in Table 4-1. The model results were then investigated at these locations and a wider review of the model results was also used to identify further potential effects.

Table 4-1: Sites identified from the desktop assessment of flooding effects

Project	Near/within existing floodplains	Works near stream crossings
NoR D1: State Highway 22 Upgrade	Flooding area upstream of Burtt Road	Upgrade of the existing Ngakoroa Bridge crossing
NoR D2: Jesmond to Waihoehoe West FTN Upgrade		
Jesmond Road FTN Upgrade section	Building at 125 Jesmond Road	No areas identified
Bremner Road FTN Upgrade section	Flooding area at Hingaia Stream Bridge crossing and Norrie Road	Upgrade of the existing Bremner Road Bridge crossing Flooding area at Hingaia Bridge crossing and Norrie Road
Waihoehoe West FTN Upgrade section	No areas identified	No areas identified
NoR D3: Waihoehoe East Upgrade	No areas identified	No areas identified
NoR D4: Ōpāheke N-S FTN Arterial	Flooding area upstream of Waihoehoe Stream crossing in the vicinity of Harry Dodd Road	New bridge crossing over Waipokapū Stream New bridge crossing over Waihoehoe Stream
NoR D5: Ponga Road and Ōpāheke Road Upgrade		
Ponga Road Upgrade section	No areas identified	No areas identified
Ōpāheke Road Rural Upgrade section	Flooding of area upstream of Ōtūwairoa Stream Bridge	Upgrade of existing Ōtūwairoa Stream Bridge by only adding additional crossings for active modes
Ōpāheke Road Urban Upgrade section	No areas identified	No areas identified

Flood modelling for the 100 ARI and 10 ARI rainfall events was carried out to study the relative impact on the likely future environment and on existing buildings within the flood plain.

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

- Drury-Ōpāheke Structure Plan 2019
- Auckland Unitary Plan Operative in Part
- Auckland Council GIS resources
- Design Drawings
- Flood modelling - flood difference maps
- Indicative Construction Methodologies
- NZTA Stormwater Specification P46

New Zealand Bridge Manual (SP/M/022) for freeboard allowance as shown in A full list of references is provided in Section 11.

- Table 4-2 below.

A full list of references is provided in Section 11.

Table 4-2: Freeboard allowance for the level of serviceability to traffic (NZ Bridge Manual)

Waterway structure	Situation	Freeboard	
		Measurement points	Depth (m)
Bridge	Normal circumstances	From the predicted flood stage 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 stage to the road surface	0.5

4.2 Site Visit

A site visit was undertaken with the project team and Auckland Council specialists to obtain an overview of the surrounding environment while performing the desktop study.

A second site visit was carried out to focus on sites identified from the desktop assessment and flood modelling:

- The Jesmond Road FTN Upgrade proposed central stormwater wetland and existing flood plain near 125 and 131 Jesmond Road (NoR D2)
- The proposed Bremner East Bridge at Norrie Road (NoR D2)
- The proposed Ōpāheke N-S FTN Arterial alignment, bridge crossings and existing properties within the flood plain in the vicinity of Harry Dodd Road (NoR D4)

- The existing Ōpāheke Road Bridge crossing over Ōtūwairoa Stream and nearby property and the proposed crossing of the Mangapū Stream (NoR D5)

4.3 Flood Modelling

4.3.1 Modelling Purpose

Flood modelling has been used to identify the potential effects of the Projects on flood levels and the extent of flooding and to demonstrate that the corridors can be constructed with an acceptable level of flooding effects.

The modelling involved the assessment of flooding effects during the 10 and 100 ARI rainfall events on the future land use with pre-project development terrain and post-project development terrain. In both scenarios, the proposed imperviousness for the MPD land use was used. That is, any differences in model scenario results are due to the change in terrain or bridges for the proposed transport corridor.

All of the catchments have Future Urban Zoned land upstream of the corridors. It is expected that significant earthworks could occur prior to implementation which will change the hydrology and hydraulics of the catchments. While the modelled scenarios use imperviousness assumptions associated with the future land use shown in the Drury Ōpāheke Structure Plans, earthworks for land development will also change the existing terrain and therefore change drainage patterns (e.g. the speed at which water is delivered and how it is stored in depressions across the catchment) and areas subject to flooding. Therefore, it is expected that further modelling will be required during the corridor detailed design phase to take account of catchment characteristics at that time and more refined corridor geometry catchment characteristics used to confirm proposed mitigation approaches.

4.3.2 Available Models

The available catchment models for the Drury Package transport corridors are summarized in Table 4-3.

Table 4-3: Auckland Council Stream Models

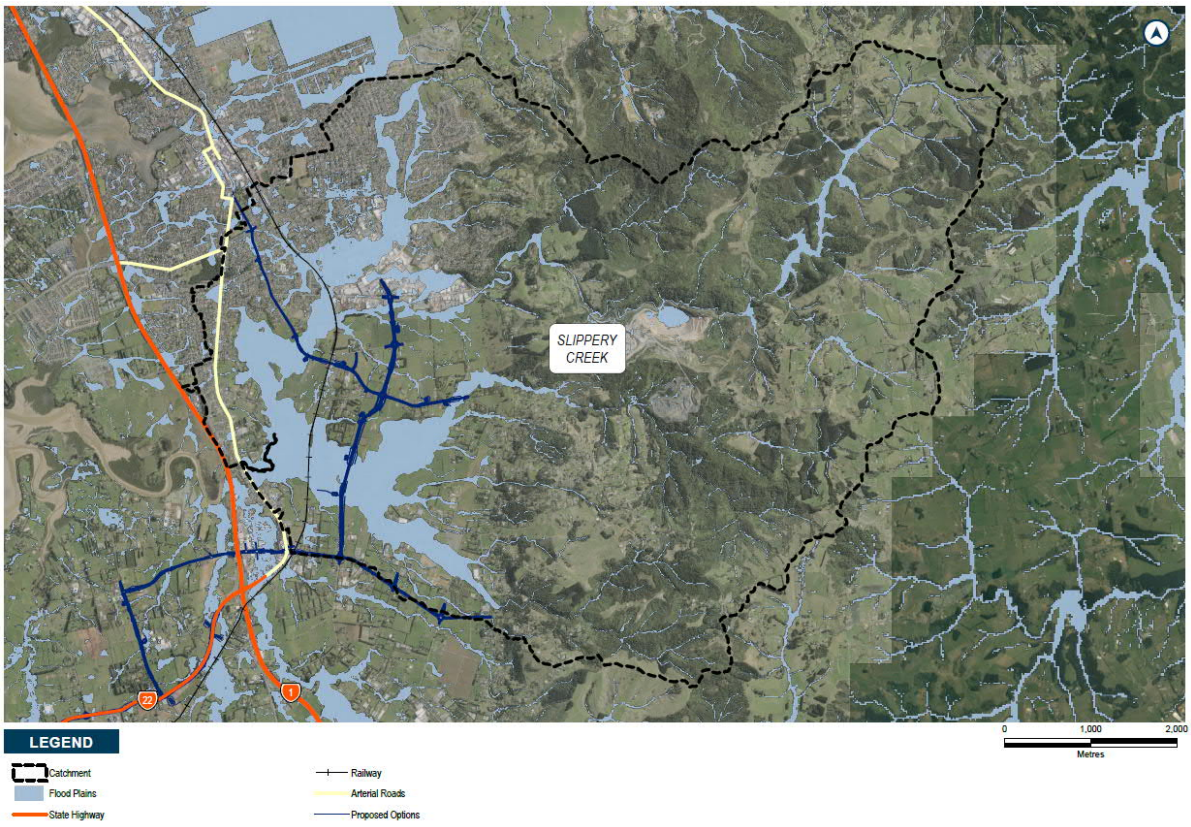
Available models	Drury Package projects within the catchment models
Slippery Creek (Infoworks ICM), Rapid Flood Hazard Assessment, 2018	Waihoehoe Road West FTN Upgrade (NoR D2) Waihoehoe Road East Upgrade (NoR D3) Ōpāheke N-S FTN Arterial (NoR D4), Ponga Road and Ōpāheke Road Upgrade (NoR D5)
Hingaia Stream (DHI MIKE) 1d/2d	Bremner Road FTN Upgrade sections (NoR D2)
Ngakoroa/Oira (Infoworks ICM), Rapid Flood Hazard Assessment, 2017	SH22 Upgrade (NoR D1) Jesmond Road and Bremner Road FTN Upgrade sections (NoR D2)

Rapid Flood Hazard Assessment models often have a relatively coarse terrain grid and, with respect to the AC Model Specification do not include stormwater drainage pipes 600 dia or smaller. Culverts have therefore been added at selected crossings of the transport corridors. The results from the models are considered appropriate to assess the relative or overall flooding effects due to the transport corridors for the current stage of design.

4.3.3 Stormwater Catchments Overview

The Drury Package projects are situated within three major stormwater catchments; Ōtūwairoa Stream (Slippery Creek), Hingaia and Ngakoroa Streams with the receiving environment known as the Drury Creek.

Ōtūwairoa Stream (Slippery Creek) is a stream network covering an area of 46.3 km². The area is drained by four main watercourses, Ōtūwairoa Stream, Waipokapū (Hays) Stream, Mangapū (Symonds) Stream, and Waihoehoe Stream, with some having extensive flood plains like the one from Waihoehoe Stream which is ±690 m wide. The Hingaia Stream is a stream covering an area of 54.9 km² within the south-eastern corner of the Auckland region. The Hingaia catchment includes wide flood plains in Ramarama and Drury areas. The Ngakoroa Stream is a watercourse network covering an area of 40.15 km² in the south of the Auckland region with wide flood plains in Runciman and Karaka areas. Each of these streams have smaller streams / tributaries and overland flow paths. The three catchments are shown in Figure 4-1.



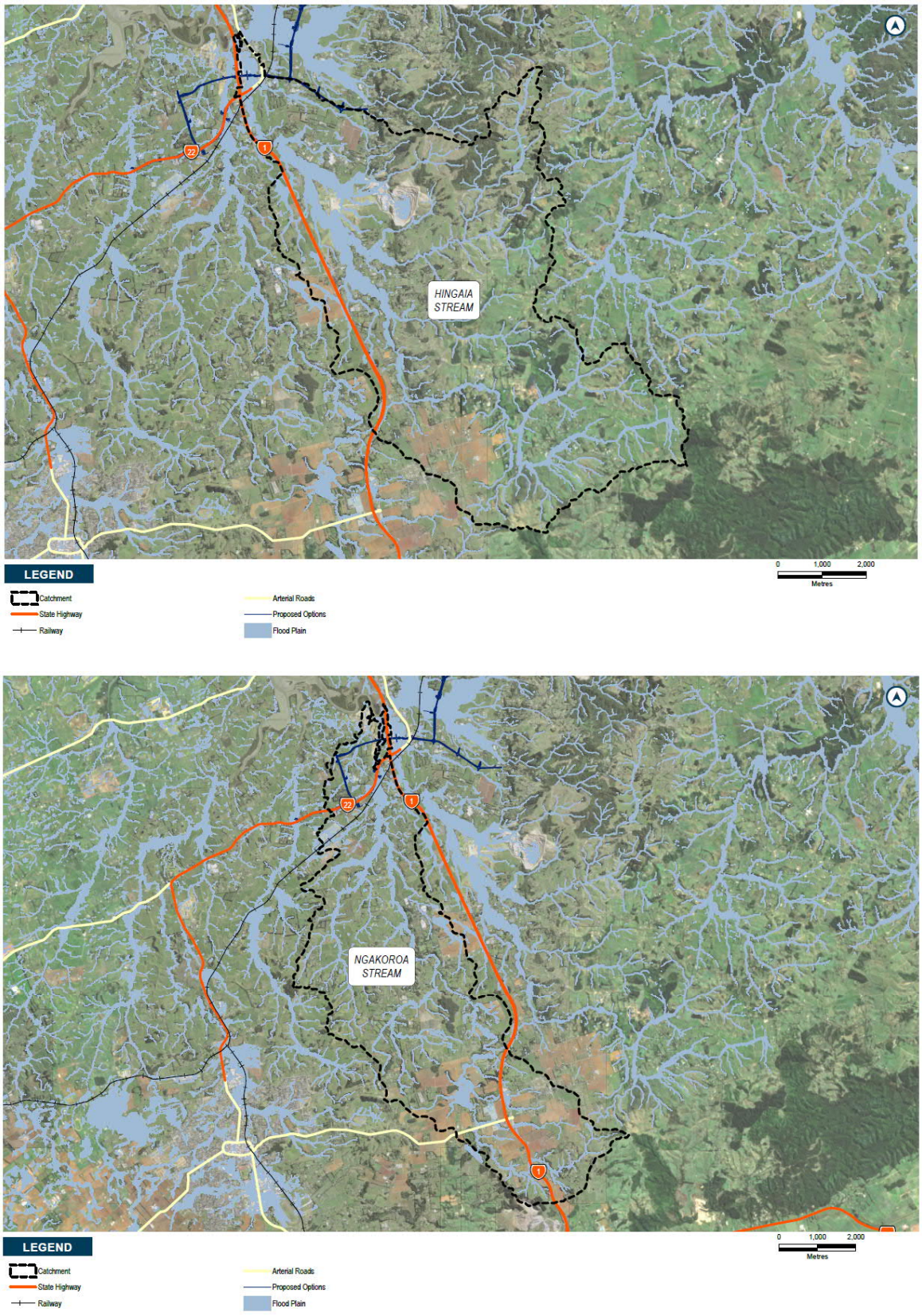


Figure 4-1: Existing 100 year ARI flood plain for Ōtūwairoa Stream (Slippery Creek), Hingaia and Ngakoroa catchments (Auckland Council GIS)

4.3.4 Modelling Scenarios

4.3.4.1 General

Models have been used to carry out a relative analysis, of the difference between flooding in the pre-project development and post-project development scenarios:

For the pre-project development (without the project in place) scenarios:

- Model the 10 year ARI rainfall event + CC event with future land-use without the design terrain in place
- Model the 100 year ARI rainfall event + CC event with future land-use without the design terrain in place

For the post-project development (with the project in place) scenarios:

- Model the 10 year ARI rainfall event + CC event with future land-use with the design terrain in place
- Model the 100 year ARI rainfall event + CC event with future land-use with the design terrain in place

4.3.4.2 Culverts

The flood model scenarios have adopted culverts as they exist in the AC models - with the addition of some new culverts/bridges to convey flows at existing overland flow paths and some extensions to existing culverts to convey flows across the new corridor terrain.

The Ngakoroa model extends existing culverts by extrapolating them at their existing grades and then linking the culvert inlet and outlet to flow depth (with the model's depth linkage method used so that the extended culverts levels can always convey flow irrespective of inverts matching ground levels). New culverts have been sized outside of the flood model and then inserted. Note that the culverts sizes are an initial estimate used to assess the relative effects of flooding outside the corridors. It is assumed that larger culverts can be constructed if required to manage effects with the size or levels of service for new or upgraded culverts being a matter for future design stages to decide. Note no culvert sizes in this report allow for fish passage requirements as set out in the National Environmental Standard for Freshwater (August 2020) and it is expected that they would increase to meet the NES. Sizes are therefore subject to detailed design and may need to be changed to address matters such as; consent requirements, asset owner requirements, level of service, stream simulation design, fish passage, blockage.

Runoff from the existing or new corridor impervious area is not attenuated in the model.

New bridges are incorporated into the model by either leaving a gap in the terrain or, where there is flood plain interaction, setting an obstruction.

4.3.4.3 Climate change

Climate change is accounted for in the model runs as per the AC modelling specification - which uses 2.1 degrees of warming and a 16% increase on rainfall. This was based on MfE's 2008 guidance.

More recent guidance by MfE from 2018 uses four Representative Concentration Pathways (RCP):

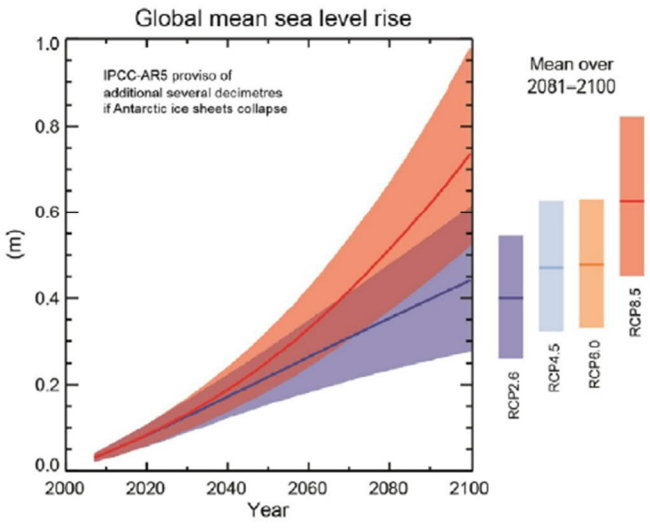
- RCP 2.6 – a positive outcome pathway which includes reduction of emissions and mitigation of some carbon already in the atmosphere
- RCP 4.5 and RCP 6 – both being pathways with "stabilisation" of emissions
- RCP 8.5 – essentially a "business as usual" pathway with very large greenhouse gas concentrations

MfE (2018) identifies for the Auckland region, that by 2090 (2081–2100, relative to 1986–2005), annual average temperatures are projected to increase by between 0.7°C (RCP2.6), 1.4°C (RCP4.5) 1.9°C (RCP6) and 3.1°C (RCP8.5). As MfE's previous guidance from 2008 had annual average temperatures for Auckland increasing by 2.1°C by 2090, the increase in temperature and rainfall allowed for in the AC models is similar to the RCP 6 pathway.

SGA have explored the impact of using the RCP 8.5 pathway in one location across the overall SGA programme of work at Okura. This identified that rainfall increased by some 35 to 40% from the baseline hydrology without any CC (compared to 16.2% used as standard in the models) and that runoff increased by approximately 25%.

Sea level rise is accounted for in the model as per MfE 2008, that is a 0.5m increase with consideration of a 0.8m change. This is considered similar to the sea level projections for both RCP 4.5 and 6 prepared under MfE's 2017 guidance. Additional allowance is made for storm surge.

Figure 23: **Intergovernmental Panel on Climate Change Fifth Assessment Report projections of global average mean sea level (MSL) rise (metres, relative to a base MSL of 1986–2005) covering the range of scenarios from RCP2.6 to RCP8.5**



4.3.5 Modelling Output

The modelling output is used to identify flooding extents and areas where the post-project development terrain results in changes in flood levels and flooding extents. These are used as a guide to assessing flood hazards. Where it was considered there was a specific constriction effect due to the Projects that might increase flood hazard, a review of water velocity was also carried out to identify if there an increased risk to the movement of people or vehicles through flood waters.

The output from the models are maps for:

- Flood levels for the 10 year ARI + CC rainfall event with future land use with existing terrain (10 year ARI pre-project development scenario)
- Flood levels for the 100 year ARI + CC rainfall event with future land use with existing terrain (100 year ARI pre-project development scenario)
- Flood levels for the 10 year ARI + CC rainfall event with future land use with design terrain (10 year ARI post-project development scenario)
- Flood levels for the 100 year ARI + CC rainfall event with future land use with design terrain (100 year ARI post-project development scenario)
- Flood level difference for the 10 year ARI + CC rainfall event with future land use (post minus pre-project development)
- Flood level difference for the 100 year ARI + CC rainfall event flood level difference with future land use (post minus pre-project development)

In assessing the flood model results, the terms positive, negligible, minor and moderate have been used in the text. The table below shows how these terms have been defined to relate to the flood model results.

Table 4-4: Flooding effects assessment criteria

Effect	Change in depth of flooding on neighbouring property	Comment	Change in habitable building floor level freeboard and freeboard is still greater than 500mm	Change in habitable building floor level freeboard and freeboard is less than 500mm	Comment
Positive	A reduction in flood level		An increase in freeboard	An increase in freeboard	
Negligible	Less than 50mm	A change in depth of flooding on land (not considering a habitable building) usually relates to loss of use of the land and a reduction in the performance of drainage systems	Less than 50mm	Not applicable	500 mm is the standard freeboard required for habitable floors. Where less than this freeboard is available, effects are considered as a higher risk.
Minor	50 to 500mm		50 to 150mm	Less than 50mm	
Moderate	Greater than 500mm		Greater than 150mm	Greater than 50mm	

5 NoR D1: Alteration to Designation 6707 - State Highway 22 Upgrade

Chapter Summary

The State Highway 22 (SH22) Upgrade consists of the widening of the existing SH22 transport corridor to a four-lane arterial standard between the State Highway 1 (SH1) Drury Interchange and the extent of the FUZ between Woodlyn Drive and Oira Road.

NoR D1 involves the widening of the transport corridor from 20 m to 30 m with batter slopes and retaining, widening of intersections, three proposed wetlands, demolition and reconstruction of the existing bridge crossing over Ngakoroa Stream, new culverts and the extension of existing culvert crossings.

The transport corridor is delineated into four sub-catchments that drain surface runoff towards three proposed wetlands for stormwater management. Wetlands 1 and 3 are sized to provide stormwater quality treatment and retention/detention for stream health. Wetland 2 is sized for stormwater quality treatment, retention/detention for stream health and flood attenuation. Wetland 2 is a joint facility with NoR D2 for part of Jesmond Rd.

The existing land use along SH22 transport corridor is mostly rural with light industry/businesses and open space. The proposed 30 m wide transport corridor encroaches on land adjacent to the existing transport corridor which is zoned Future Urban and Open Space under the AUPOIP. Existing flood prone areas, overland flow paths/streams, and 100 year ARI flood plains are evident alongside parts of the SH22 corridor and the proposed design of the SH22 upgrade has taken these constraints into account.

This assessment considers the potential flooding hazard effect of the upgraded transport corridor during its construction and operational phases on the flood extents and levels in the surrounding area.

It is anticipated that culverts will either be constructed entirely offline or with temporary damming sufficiently catering for catchment flows during works, with minimal impacts to existing watercourses and overland flow paths. Temporary platforms and localised flow diversion will be required for bridge demolition and construction works over the Ngakoroa Stream.

There may be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridge. However, the details of the construction approach have yet to be confirmed at this time. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this will be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

The operational phase flooding effects of NoRD1 have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development

terrain) flood model results. The 100 year ARI depth difference maps show an overall reduction in flood water levels at the bridge.

The flood hazard effect during the operation of the Project is positive due to the greater conveyance capacity of the new Ngakoroa Stream Bridge and raising the bridge. This results in much improved freeboard to the bridge (with benefits to the safe passage of flow and safety of those using the bridge). There is an existing (and potential future) adverse effect with an increased depth of flooding over SH22 near Burberry Road. Design refinements and/or minor matters that need to be addressed further at detailed design have been identified and should be addressed through conditions on the proposed designation that identify key outcomes to be achieved. There is space within the designation sought for the works required for stormwater and flood mitigation.

5.1 Project Description

5.1.1 Project Overview

The State Highway 22 (SH22) Upgrade (NoR D1) consists of the widening of SH22 to a four-lane arterial with separated walking and cycling facilities. The Project extends approximately 3.08km from the State Highway 1 (SH1) Drury Interchange in the east, and the extent of the FUZ between Woodlyn Drive and slightly beyond Oira Road in the west. The intersections at Jesmond Road and Great South Road will be signalised and a roundabout is proposed at Oira Road. An overview of the concept design is provided in Figure 5-1.

As the surrounding area is urbanised over time and alternative routes are implemented (particularly the proposed Pukekohe Expressway), the function of SH22 will change from a rural state highway to provide an appropriate urban arterial connecting the growth areas of Drury West to the wider network and centres, including providing a frequent transport bus network. This is likely to include a reduction in the speed limit to 50kph. SH22 will improve future connectivity to the proposed Drury West train station which currently forms part of the New Zealand Upgrade Programme (NZUP) project.

Figure 5-1: Overview of SH 22 Upgrade

The indicative alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment will be refined and confirmed at the detailed design stage. Key features of the proposed upgrade include the following:

- Widening of SH22 from its current general width of 20m to enable a 30m wide four-lane road with separated walking and cycling facilities
- Localised widening around the existing intersections to accommodate for vehicle stacking and tie-ins and walking and cycling facilities/crossings
- Demolition and reconstruction of the existing Ngakoroa Stream Bridge
- Proposed new and extended culverts
- Three proposed stormwater wetlands
- Batter slopes and retaining to enable widening of the corridor, and associated cut and fill activities
- Vegetation removal along the existing road corridor
- Areas identified for construction related activities including site compounds, construction laydown, bridge works area, the re-grade of driveways and construction traffic manoeuvring.

5.1.2 Project Features

Stormwater catchments and features are shown on the layout plan for NoR D1 in Appendix 1. Four sub-catchments are created along the transport corridor. Runoff from catchment 1 is to be treated within the corridor designation while catchment 2A (between chainage 1740-2900) flow to stormwater Wetland 1 with an outflow into a tributary of the Ngakoroa Stream. Catchment 2B between chainage 2900 and 3480 is treated and attenuated in Wetland 2. Runoff from catchment 3 is collected at a low point (chainage 3980m) and conveyed via a pipe system to join with the flow in catchment 4. The flow from catchment 4 discharges into Wetland 3 with an outflow into Oira Creek.

The proposed transport corridor is designed to follow the existing ground level as far as possible while it crosses Ngakoroa Stream and a few overland flow paths. The longitudinal slopes range between 0.3% and 6.5% which allows for enough gradient to drain stormwater runoff from the transport corridor via catchpits into an underground pipe system.

Where discharge points are north of SH22, there are no existing flooding issues identified in either the Ngakoroa Stream or Oira Creek and no flood attenuation is provided. Where the discharge is to the Ngakoroa Stream upstream of the Ngakoroa Bridge, existing flooding issues may be present and the increased surface runoff generated by the additional impervious surface due to the wider transport corridor, requires flood storage (using ponds/wetlands) to attenuate and discharge at the 100 ARI pre-project development peak flow.

The total catchment sizes summarized in Table 5-1 include both the impervious and pervious areas for that catchment.

Table 5-1: SH22 Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management type	Size of wetland permanent water	Discharge point location
1	chainage 1620-1740 (low point at chainage 1620)	3 600 m²	Stormwater treatment within the corridor	n/a	Ngakoroa Stream at 50R Karaka Road, Drury
2A	Chainage 1740-2900 (low point at chainage 2100)	34 800 m²	Wetland 1 for quality treatment, retention and detention	670 m³	
2B	chainage 2900-3480, plus Jesmond catchment between chainage 2000- 2360. (low point in Jesmond Rd at chainage 2140)	22 800 m²+ 10 800 m²	Wetland 2 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year rainfall event	668 m³	Unnamed stream at 110 Karaka Road, Drury
3	chainage 3480-4040 (low point at chainage 3980)	17 400 m²	Wetland 3 for quality treatment, retention and detention	623 m³	Oira Creek at 462 Karaka Road, Drury
4	chainage 4040-4160 (low point at chainage 4160)	15 000 m²			

The existing cross drainage for this transport corridor consists of the Ngakoroa Stream Bridge and two culvert crossings. The existing bridge is an obstruction to flood flows with overtopping occurring on the western approach. It is proposed to upgrade the existing bridge to a new structure and upgrade the existing culvert with new extensions. The existing and proposed cross drainage is summarized in Table 5-2.

A potential set of cross drainage structures for this transport corridor are used to assess the potential flooding effects and are summarized in Table 5-2. The type and size of cross drainage structures are not fixed and will continue to be assessed through subsequent regional consenting and design phases.

Table 5-2: SH22 Upgrade cross drainage characteristics

Chainage	Upstream catchment	Existing Cross drainage	Existing Bridge Levels (RL)	Modelled Cross drainage	Modelled Bridge Levels (RL)
chainage 1690	3795 ha	Ngakoroa Stream Bridge structure, three-span, 55.9m long	Soffit level at 4.58m.	Ngakoroa Stream Bridge structure, three-span, 60m long	Soffit level at 7.4m.
chainage 2200	2.41 ha	Assumed 300mm dia. culvert		750mm dia. culvert	
chainage 2320	22.08 ha	750mm dia. culvert		900mm dia. culvert	

5.2 Existing and Likely Future Environment

The existing land use along the SH22 transport corridor is mostly rural with some associated businesses and open space. An artificial pond between chainage 2300 and 2500 is situated on the northern side and discharges through a culvert crossing under SH22 into the Ngakoroa Stream. The Ngakoroa Stream runs through the Ngakoroa Reserve and crosses the transport corridor under a bridge structure at chainage 1690m.

The current zoning in the AUPOIP is FUZ and Open Space. With reference to the Auckland Council Drury-Ōpāheke Structure Plan and developer plans, the future land use for the FUZ is proposed to be urban, likely consisting of Terrace Housing and Apartment Buildings, Local Centre and Mixed Housing Urban/Suburban and Light Industry at the north eastern extent of the Project. Permanent and intermittent streams with a 20 m riparian margin, flood plains and a coastal inundation 1 per cent AEP plus 1 m control are also included in the Drury-Ōpāheke Structure plan. The existing open spaces like the Ngakoroa Reserve and Drury Sports Complex are not likely to change in the future.

Existing flood prone areas from Auckland GeoMaps are evident alongside SH22 where overland flow paths drain towards Ngakoroa Stream. The AC Geomaps 100 year ARI flood maps show flooding in the Ngakoroa Reserve and overtopping of the existing western approach to the Ngakoroa Bridge.

Earthworks for development within the FUZ will change catchment hydrology, the terrain and building and property types that are potentially exposed to flooding. The assessment has therefore considered specific effects on existing properties and more generally considered effects on potential future development. It is expected that coordination and integration of the corridor design with FUZ development will be required to confirm and address potential future effects.

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

This report assesses the impacts from construction and operation due to the flood extents and changes in water levels caused by the upgraded transport corridor. A 2D flood model for the Ngakoroa catchment has been generated for the pre- and post-project development scenarios for the 10 year and 100 year ARI rainfall events. This assessment of effects refers to the flood model results and considers the flooding extents at the existing and new culvert crossings, bridge structures and significant areas where the new road embankment encroaches existing flood plains. Table 5-3 summarizes the existing (pre-project development) and future (post-project development) flood levels.

Table 5-3: SH22 Upgrade existing and future flood levels at key crossings

Chainage	Existing Cross drainage	Existing Bridge Levels (RL)	Existing flood level (MPD + CC) (RL)	Modelled Cross drainage	Modelled Bridge Levels (RL)	Future flood level (MPD + CC) (RL)
chainage 1690	Ngakoroa Stream bridge structure, three-span, 55.9m long	Bridge soffit level at 4.58m	10 year ARI: 4.88m upstream, 4.79m down-stream	Ngakoroa Stream Bridge structure, three-span, 60m long	Bridge soffit level at 7.4m	10 year ARI: 4.84m upstream, 4.75m downstream
			100 year ARI: 6.45m upstream, 6.33m down-stream			100 year ARI: 6.32m upstream, 6.22m down-stream
chainage 2200	Assumed 300mm dia. culvert Existing road level 6.43 at chainage 2040		10 year ARI: 6.12m upstream, 5.60m down-stream	750mm dia. culvert Proposed road level 6.20m at chainage 2120		10 year ARI: 6.13m upstream, 5.64m down-stream
			100 year ARI: 6.99m upstream, 7.01m down-stream [2]			100 year ARI: 7.01m upstream, 7.03m downstream [2]
chainage 2320	750mm dia. culvert Existing road level 7.91m		10 year ARI: 6.56m upstream, 5.72m down-stream [2]	900mm dia. culvert Proposed road level 8.15m		10 year ARI: 6.63m upstream, 5.75m down-stream [2]
			100 year ARI: 7.00m upstream, 7.03m down-stream [2]			100 year ARI: 7.03m upstream, 7.06m down-stream [2]

[2] Flood levels for upstream and downstream reflect different conditions occurring at different times during the rainfall event

5.3.1 Positive Effects

The new bridge over the Ngakoroa Stream provides a significant improvement to flood resilience.

The existing bridge over Ngakoroa Stream obstructs flow by 1.8m during a 100 year ARI rainfall event – i.e. the bridge has negative freeboard. The proposed SH22 upgrade concept has 1.08m freeboard between the 100 year flood level and bridge soffit which provides a significant increase to the bridge's resilience to flooding.

Upstream of the bridge, the 100 year ARI flood difference shows there is a decrease in water levels. The likely future environment near the bridge crossing is urban and Open Space – Active and Recreation Zone.

5.3.2 Assessment of Construction Effects

The proposed works related to flooding effects are:

- demolition and reconstruction of the existing bridge crossing over Ngakoroa Stream
- two existing culverts require extending/upgrading to accommodate the transport corridor widening at chainage 2200 and 2320
- three new wetlands

The bridge over the Ngakoroa Stream will require temporary staging platforms for piling rigs and cranes to be constructed on the banks and possibly over the stream bed. These platforms could cause a constriction to flood flows and cause a backwater effect raising upstream flood levels. The combination of a temporary constriction at the bridge and an extreme flood means there is an elevated risk of flooding over the Ngakoroa Reserve for the duration of the temporary works and existing bridge being in place. Note that the existing levels of the western approach mean it would overtop at RL6.4 approx. and prevent this potential effect extending onto existing upstream properties.

A construction yard is proposed on the north-western side of the Ngakoroa Stream partially within the 100 year flood level. The north-western side of the bridge is downstream of the bridge will be a relatively low velocity area for flow with no more than minor adverse effects on flooding expected. Other construction yards and stockpile sites are also proposed along the transport corridor. These locations are outside flood plains and major overland flow paths and therefore do not present increased flood hazard risks. Construction yard locations will be confirmed during the construction phase and therefore siting them with respect to flooding constraints should be considered further through the CEMP.

The culverts to be installed or upgraded can be constructed offline from existing flow paths or use diversions or over-pumping to isolate working areas. Therefore, it is expected that flooding effects can be appropriately managed during the construction phase.

Section 5.3.3 below describes methods for minimising/mitigating these potential effects.

5.3.3 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Ngakoroa Stream Bridge

Temporary platforms will be constructed on the banks and over the bed using driven steel piles. Piling rigs will sit on top of the platforms to construct the bridge piers. To minimise the risk of flooding, temporary works need to be set back as far as practicable from the main stream channel. Stockpiling of materials outside the flood plain will also mitigate the potential for blocking flow paths and flood plains.

Timing construction works during the dry season when extended periods of low flow are expected will play a key role in minimising the potential for flooding.

Culverts

Culvert works should be constructed during the initial phase of construction so that flows can be diverted across the construction site to maintain functionality. Sufficient clearance from inlets and outlets for earthworks operations is needed to reduce the risk of blockages or constrictions leading to flooding. Temporary diversions or over-pumping will be required to divert clean water away from the existing culverts to allow for extension works or will be maintained through the existing culvert while new culverts are constructed alongside. Works should be planned for dry weather/summer conditions to facilitate flow management and reduce the risk of flooding.

Mitigation

Flood hazard risks for the construction phase should be addressed in a Construction Environmental Management Plan (CEMP). In preparing the CEMP, key issues to consider are:

- siting construction yards and stockpiles with minimal effects on flood flows
- minimising the physical obstruction to flood flows under the existing bridge from temporary works
- staging and programming to carry out work when there is less risk of high flow events, and
- methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

5.3.4 Assessment of Operational Effects

Operational effects have been assessed through flood modelling to consider the flooding extents at culvert crossings, bridge structure and areas where the new road embankment significantly encroaches existing flood plains or major overland flow paths. The assessment also considers the extents of flooding on existing properties due to the proposed SH22 upgrade. The following areas are identified and described in more detail in the sections below:

- SH22 / Ngakoroa Stream Bridge
- Existing culvert crossings at chainage 2200 and 2320

5.3.4.1 SH22 / Ngakoroa Stream Bridge

The pre-project development 100 year ARI flood modelling results give the water level as 6.45 m upstream and 6.33 m downstream of the bridge crossing. The existing bridge soffit level is at 4.58 m resulting in negative freeboard of 1.8m and the bridge forming a significant obstruction to flood flows.

The post-project development results give the water level reducing to 6.32 m (-0.13 m) upstream and 6.22m (-0.11m) downstream. Upstream of the bridge, the 100 year ARI flood difference map in Figure 5-2 shows there is an overall decrease in water levels.

The likely future environment near the bridge crossing is urban and Open Space – Active and Recreation Zone. The reduction in water levels in this area provides a safer environment for the public and a lower risk for future flooding on upstream public roads, the nearby Ngakoroa Reserve and future urban development.

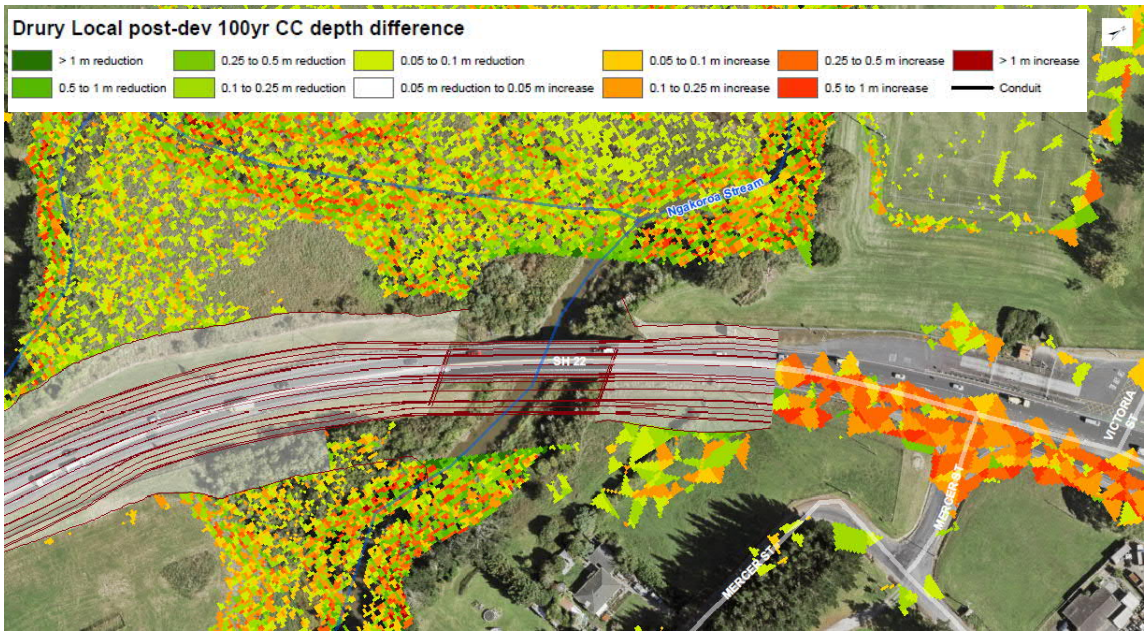


Figure 5-2: 100 Year difference map for post- minus pre-project development at SH22 and Ngakoroa Stream crossing

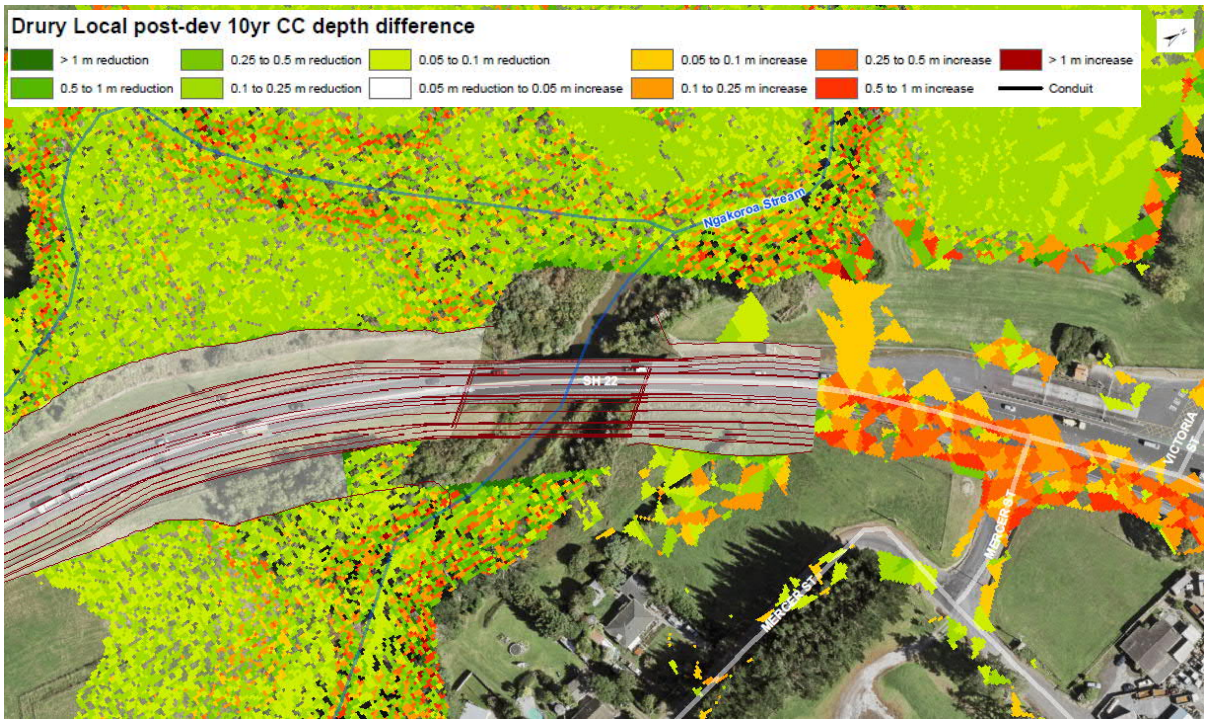


Figure 5-3: 10 Year difference map for post- minus pre-project development at SH22 and Ngakoroa Stream crossing

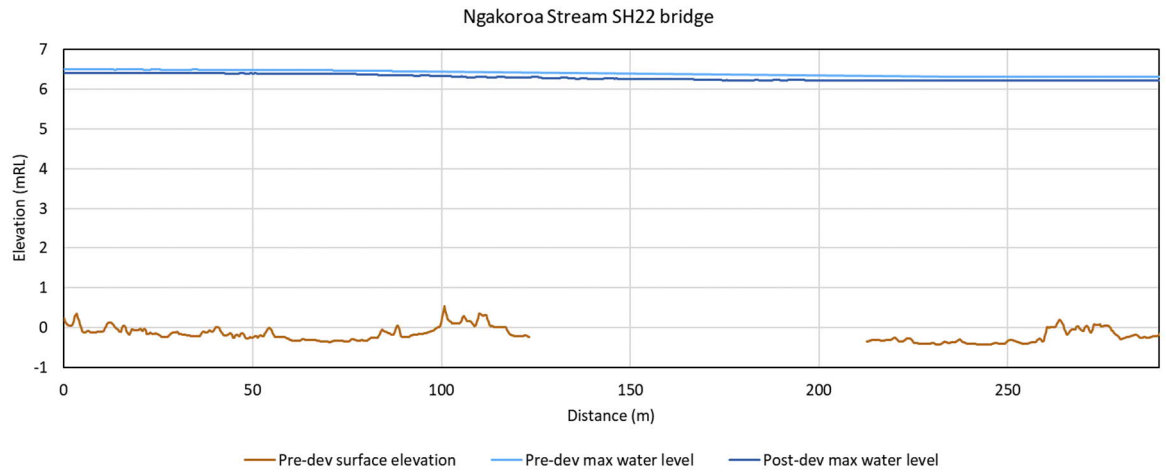


Figure 5-4: Hydraulic grade line (100 ARI) at SH22 and Ngakoroa Stream crossing

5.3.4.2 Crossings at chainage 2200 and 2320

Both existing culverts head up water in the 100 year ARI rainfall event which leads to overtopping the road at the nearby low point. Refer to Table 5-3 for details of the pre-Project and post-Project flood levels.

The 100 year ARI difference maps in Figure 5-5 present the post-Project flood levels minus the pre-project development water levels. These culverts drain from north to south, but the tailwater within the Reserve potentially causes reverse flow under some conditions.

At all culvert inlets there is a risk of flooding from blockage from upstream debris. These could be addressed through overland flow paths, upsizing culverts and secondary inlets and should be considered further at detailed design. It is recommended to include a condition in the proposed designation outlining matters to be considered further at detailed design.

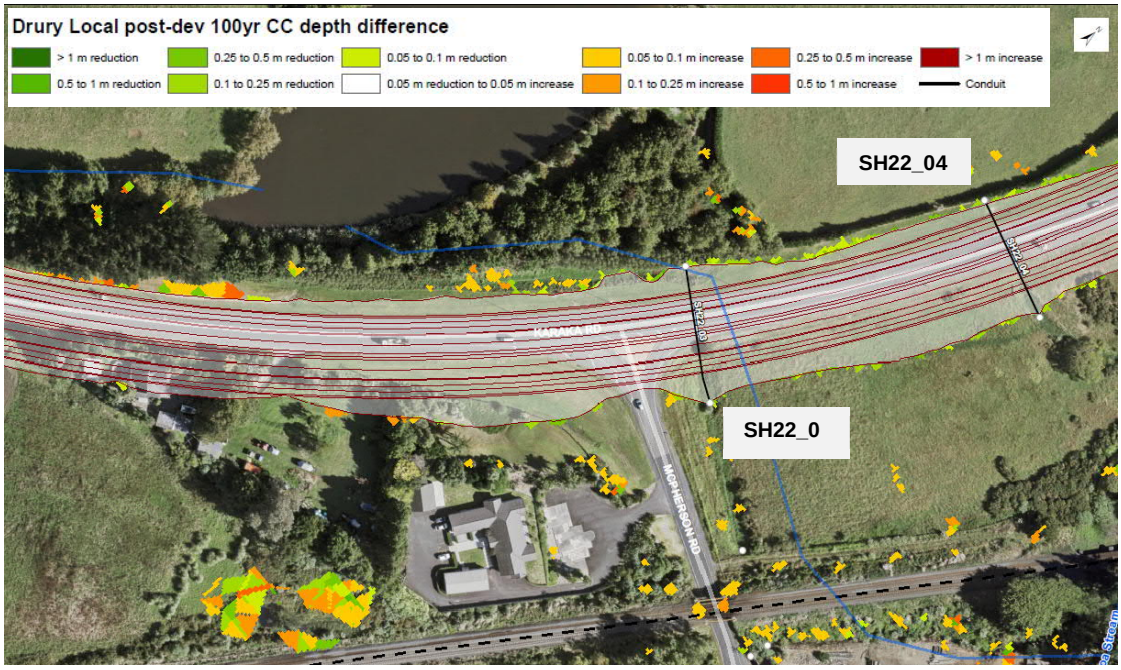


Figure 5-5: 100 Year difference map for post- minus pre-project development at SH22 and existing crossing at chainage 2320 (SH22-03) and at chainage 2200 (SH22-04)

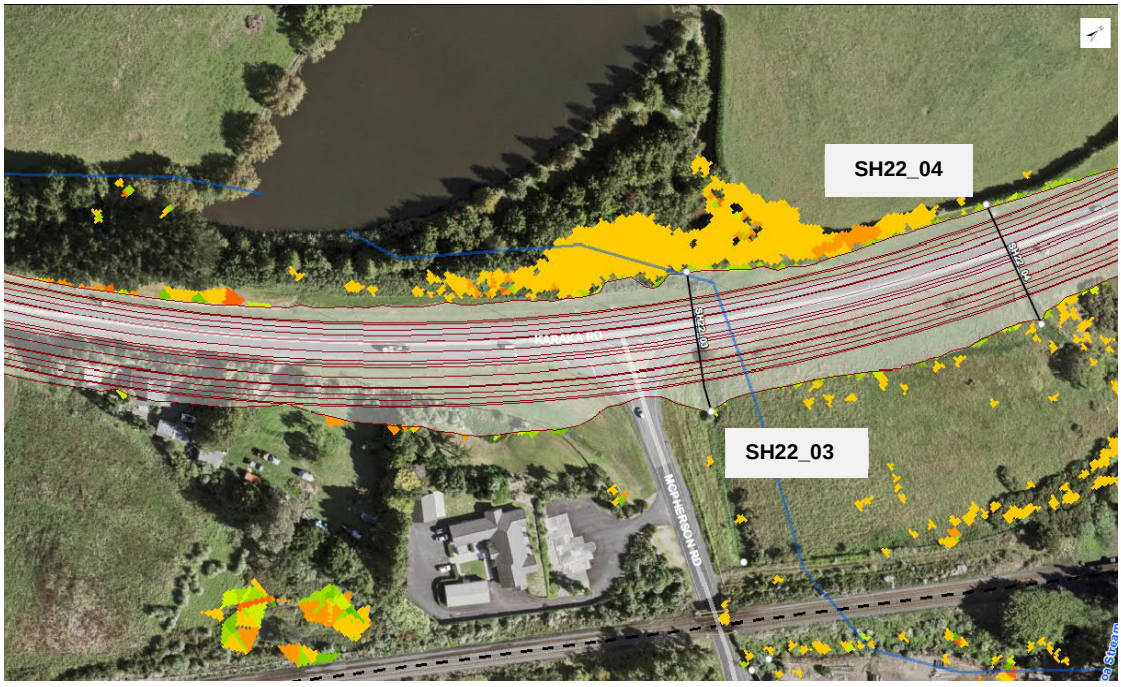


Figure 5-6: 10 Year difference map for post- minus pre-project development at SH22 and existing crossing at chainage 2320 (SH22-03) and at chainage 2200 (SH22-04)

5.3.4.3 Property Assessment

As identified above there is a reduction in the 100 year flood level upstream of the Ngakoroa Bridge and minor changes in flood levels at the existing culverts. A review of the flood velocity below the bridge location shows that the post development scenario has lower velocities but that within some 50m either side of the bridge, the velocity fields are similar. This suggests the flood hazard across the reserve is unchanged. The proposed levels for the sag point on SH22 are slightly lower than the existing and this allows water to spill from the reserve earlier than the current arrangement and increase the potential depth of water across the road (with a maximum depth of 0.25m). The sag point on the road should be raised above the flood level in the reserve or a small bund constructed on the southern side to mitigate this risk, or this risk confirmed to be minor (and therefore not requiring mitigation) during detailed design.

According to the Auckland Council Modelling Specification a freeboard of 500 mm should be added on top of the 100 year ARI MPD flood level for habitable floor levels to have adequate freeboard and be safe for use. Buildings floors potentially affected by flood hazards are counted either as being below the 100 year flood level or within 500 mm of the 100 year flood level. Driveways and parking areas should be kept safe from flooding with allowable water depths below 150 mm for cars and 300 mm for trucks.

Figure 5-7 presents the post-project minus the pre-project development water levels for the 100 year rainfall events. No existing private property is considered to be affected in more than a minor way by the SH22 upgrade works. The area (point A in Figure 5-7) within the Ngakoroa Reserve has a water level increase of 0.01 m which is considered a negligible effect.

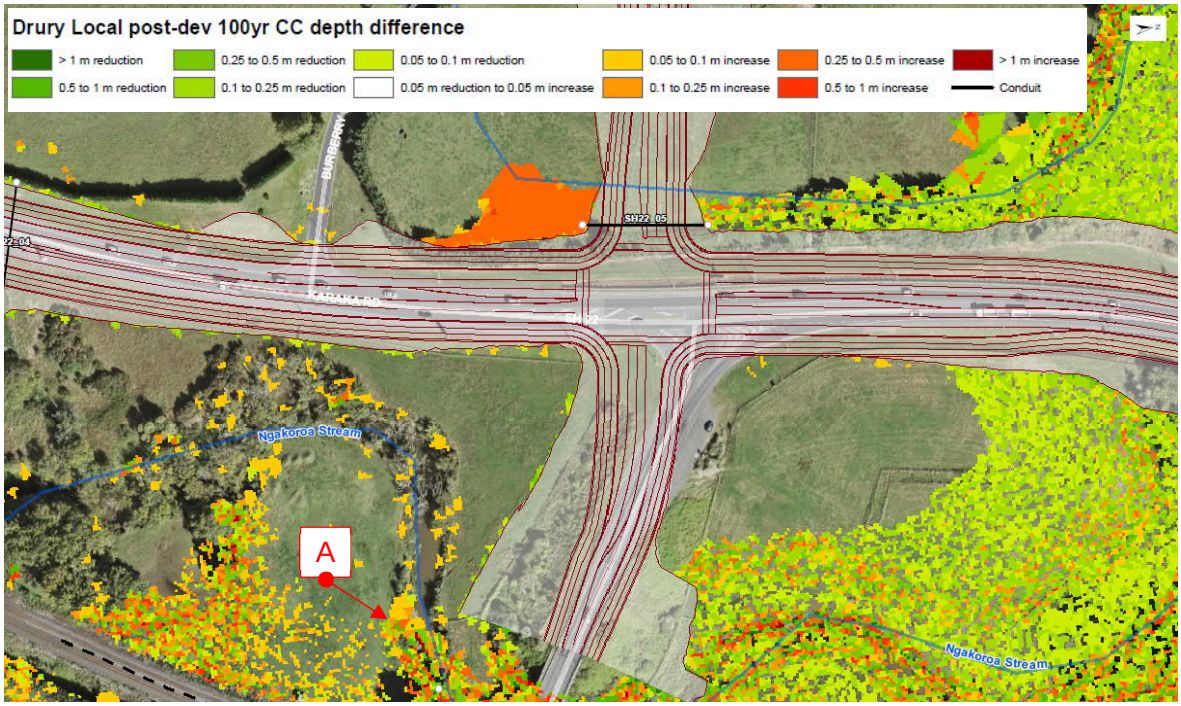


Figure 5-7: Property assessment locations (Point A) on the 100 year ARI depth difference map for SH22

Table 5-4: Properties potentially at risk of flooding along SH22 upgrade

Point on difference map	Property address	Affected area	Depth difference for 100-year post minus pre-project development	100-year flood level (RL)	Comments
Point A	Ngakoroa Reserve	Open space	+ 0.01m	Pre-dev: 6.76m Post-dev: 6.77m	Increase in flood level less than 50mm; negligible

5.3.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

There will be improved freeboard for flood flows to the proposed Ngakoroa Bridge compared to the existing bridge.

The risk of flooding from culvert blockage could be addressed by upsizing the culverts or providing secondary inlets and this should be considered further at detailed design.

The sag point on SH22 adjacent to the Ngakoroa Reserve should be raised above the flood level in the reserve or a small bund constructed on the southern side so the flood hazard across SH22 is not increased - or confirmed to be minor and therefore no mitigation is required. This will be addressed through normal Waka Kotahi design processes and application of appropriate specifications and codes of practices.

5.4 Conclusion

The potential construction phase flooding effects can be appropriately managed and with the proposed CEMP addressing flood risk, flooding effects are expected to be minor.

Overall, the SH22 Upgrade will have a positive effect on flood hazard risks at the Ngakoroa Bridge due to improved freeboard and slight decreases in flood depth and velocity.

There is a risk of flooding from culvert blockage which could be addressed through overland flow paths, upsizing culverts and secondary inlets and this should be considered further at detailed design. A slight increase in flood hazard at the sag point at chainage 2100 can be mitigated by raising the vertical alignment or creating a diversion bund on the south side. It is recommended that this be addressed through a condition identifying key outcomes to be achieved, requiring this issue be given further consideration at detailed design.

5.4.1 Recommendations for NoR D1 Conditions

Construction effects

It is recommended that a CEMP be prepared before construction commences. The CEMP will consider and mitigate potential adverse flood hazard effects. The flood hazard effects shall be assessed by an experienced Stormwater Engineer and shall consider the effects of temporary works,

earthworks, storage of materials and temporary diversion and drainage on flow paths, flow depth and velocity.

Operational effects

It is recommended that during detailed design, that flood modelling of the pre project and post project 100 year ARI flood levels (both for MPD land use and including climate change) is carried out and measures implemented to achieve the following outcomes:

1. 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)
2. 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)
3. 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
4. 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)
5. that there is no more than a 10% average increase of flood hazard (defined as flow depth times velocity) for main access to authorised habitable dwellings.

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

6 NoR D2: Jesmond to Waihoehoe West FTN Upgrade

Chapter Summary

NoR D2 comprises a four-lane frequent transit network from the intersection of SH22/ Jesmond Road, via Bremner Road, to the intersection of Norrie Road/Great South Road. The NoR comprises three sections; Jesmond Road, Bremner Road and Waihoehoe Road (west).

The Jesmond Road FTN Upgrade proposes widening the existing road to a four-lane FTN arterial standard between the Jesmond Road/SH22 intersection in the south to just past the intersection with the future Jesmond to Bremner link (Auranga Road 1) in the north. The transport corridor is delineated into four sub-catchments that drain towards three proposed wetlands for stormwater management. Wetlands 1 and 2 are sized to provide stormwater quality treatment and retention/detention for stream health. The joint wetland with NoR D2 is sized for stormwater quality treatment, retention/detention for stream health and flood attenuation.

The Bremner Road FTN Upgrade proposes a new transport corridor from Jesmond Road to Bremner Road through Auranga Development (Jesmond to Bremner Link) and the widening of, and new connection between, the existing Bremner Road and Norrie Road in Drury East. The new and widened transport corridor along Bremner Road and Norrie Road will enable a four-lane FTN arterial standard between Jesmond Road in the west to the end of Norrie Road in the east. The transport corridor is delineated into four sub-catchments that drain towards stormwater management devices, such as raingardens, on both sides of the corridor, sized to provide stormwater quality treatment and retention/detention for stream health. Flood attenuation is not allowed for in devices along Bremner Road as these all discharge in the bottom third of their catchments.

The Waihoehoe Road West FTN Upgrade proposes widening on Waihoehoe Road to a four-lane FTN arterial standard including the intersection at Great South Road in the west to Fitzgerald Road / proposed Ōpāheke N-S Arterial in the east. The transport corridor is delineated into two sub-catchments that drain into a pipe system and discharge into a nearby overland flow path or stream. Stormwater treatment and retention/detention will be provided within the designation sought. Flood attenuation is not proposed as the discharges will be to the lower reaches of the Hingaia Stream.

The scope of works for the NoR includes a new bridge at an unnamed stream west of the Auranga development and replacement of bridges over the Ngakoroa and Hingaia Streams.

The existing land use along Jesmond Road and Waihoehoe Road West is generally rural-residential with land zoned Future Urban. The existing Bremner Road environment changes from the Drury 1 Precinct plan (Auranga Development) in the west to Light Industry/Business east of SH1 with Open Space around the Ngakoroa and Hingaia Streams.

Existing flood prone areas, overland flow path/stream crossings, and 100 year ARI flood plains are present at low points along Jesmond Road, the Bremner Road crossing over the Ngakoroa Stream and the commercial area around the Hingaia Stream. These constraints have been considered in developing the concept design.

This assessment considers the potential flooding hazard effects of the upgraded transport corridor during its construction and operation.

Temporary platforms and local diversions will be required over streams for bridge demolition works and construction. It is anticipated that culverts will either be constructed entirely offline or with temporary damming sufficiently catering for catchment flows during works, with minimal impacts to existing watercourses and overland flow paths.

There may be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridges. However, the details of the construction approach have yet to be confirmed at this time. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this will be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

The operational phase flooding effects of NoRD1 have been assessed using the difference between the existing (pre-project development) and future (post-project development) flood model results.

The Jesmond Road FTN Upgrade could increase operational phase flood levels and create flood prone areas upstream of the sag points where overland flow crosses the transport corridor. This could have effects on future urban development upstream. With careful design of road levels, upsizing of culverts and providing inlet protection, flood levels can be managed to pre Project levels. Construction of a diversion drain at 119, 125 and 131 Jesmond Road will direct overland flow away from the buildings on site, lower flood levels and could improve the existing situation. Specific matters are recommended as conditions on the proposed designation to address these matters at detailed design.

Using a culvert, there is a potential increase in flood levels greater than 0.5m and creation of a flood prone area affecting future residential development upstream of the proposed transport corridor at chainage 600 on Bremner Road. In addition, as the upstream catchment is 115 ha (generating large flows) and a culvert alternative would be long and large (with consequent ecological effects), a bridge is proposed. A stream diversion is likely required on the upstream side to keep the bridge length to a single span.

The vertical alignment of the Bremner Road Bridge over the Ngakoroa Stream is to be changed to accommodate the SH 1 widening works for the Waka Kotahi Papakura to Drury South project with the construction of a new two lane bridge over Ngakoroa stream. In the future, when Bremner Road is upgraded as part of the Jesmond to Waihoehoe Road West FTN Upgrade, the existing bridge will either be widened or a new bridge constructed alongside it to provide two additional lanes. However, existing Transpower overhead 220kv lines limit how much the vertical alignment of the bridges can be raised to address flood risk events. The future bridge will be higher than the existing one and have improved flood resilience with less frequent overtopping on the western approach and have a smaller part of the bridge support structure submerged. Flood flow velocity is relatively low at the bridge and by using a span of 40m for the bridge there will be a 160 mm drop in flood levels upstream during the 100 year ARI rainfall event. As the bridge beams are partly submerged there is a risk of debris collecting on the bridge. Further coordination is expected to

confirm the approach that is best able to meet the objectives of both the Bremner FTN and Papakura to Drury South projects.

There will also be a reduction in upstream flooding as a result of the replacement and new alignment for the Hingaia Stream Bridge. The existing Norrie Road/Hingaia Stream Bridge is set below the 100 year flood levels and increases upstream flood levels. The proposed new bridge is higher with longer spans, which will provide greater flood freeboard to the corridor and improve resilience. The Bremner Road/Firth St intersection is subject to flooding in both pre and post development scenarios for the 10 and 100 year ARI rainfall events. Temporary road closures may be required for mitigation.

It is recommended that the designation include a condition requiring the existing Norrie Road Bridge be fully removed once the construction phase is over and the new bridge over Hingaia Stream is operational so that the reduction in upstream flooding is realised. The Bremner Road/Firth St intersection is subject to flooding in both pre and post development scenarios for the 10 and 100 year ARI rainfall events. No new mitigation measures are required. Temporary, infrequent road closure may be required during these events, as it is in the pre-development scenario.

There are no significant flooding effects from the Waihoehoe Road West section of the corridor as it is located on a ridge and does not encroach on to any flood plains or overland flow paths.

The overall effect of NoR D2 on flooding is positive or can be adequately mitigated within the designation assuming the recommendations above are implemented. Other design refinements and/or minor matters that need to be addressed further at detailed design have been identified. A condition on the proposed designation is recommended to address the key flooding effects that could arise.

6.1 Project Description

The Jesmond to Waihoehoe West FTN Project (NoR D2) includes, an approximately 4.1 km long four-lane FTN arterial route along Jesmond Road, through a new greenfields link between Jesmond Road and the existing Bremner Road, Bremner Road, Norrie Road and Waihoehoe Road West. It primarily involves upgrading and widening existing transport corridors with the exception of the new link between Jesmond Road and the existing Bremner Road and the new bridge connection over Hingaia Stream. The functional intent of the Project is to provide an appropriate urban arterial connecting the growth areas of Drury West to the wider network and centres, including providing a frequent transport bus network. Generally, a 30m wide transport corridor will be provided with two general traffic lanes, two bus lanes and separated walking and cycling facilities on both sides of the road corridor. The urban arterials will have a likely speed limit of 50kph.

For assessment purposes, the Project has been separated into three sections, as shown in Figure 6-1, including:

- Jesmond Road FTN Upgrade;
- Bremner Road FTN Upgrade (including the Jesmond to Bremner link through the Auranga Development, Bremner Road and Norrie Road); and
- Waihoehoe Road West FTN Upgrade including the Great South Road intersection.

The indicative alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment will be refined and confirmed at the detailed design stage. Key features of the proposed upgrade common to each Project section include the following:

- A typically 30m wide road with four lanes and separated walking and cycling facilities
- Localised widening around the existing intersections to accommodate for vehicle stacking and tie-ins and walking and cycling facilities/crossings
- Batter slopes and retaining to enable widening of the corridor and/or wetland construction, and associated cut and fill activities
- Vegetation removal along the existing road corridor
- Areas identified for construction related activities including site compounds, construction laydown, bridge works area, the re-grade of driveways and construction traffic manoeuvring.

Further details of each Project section are provided below.

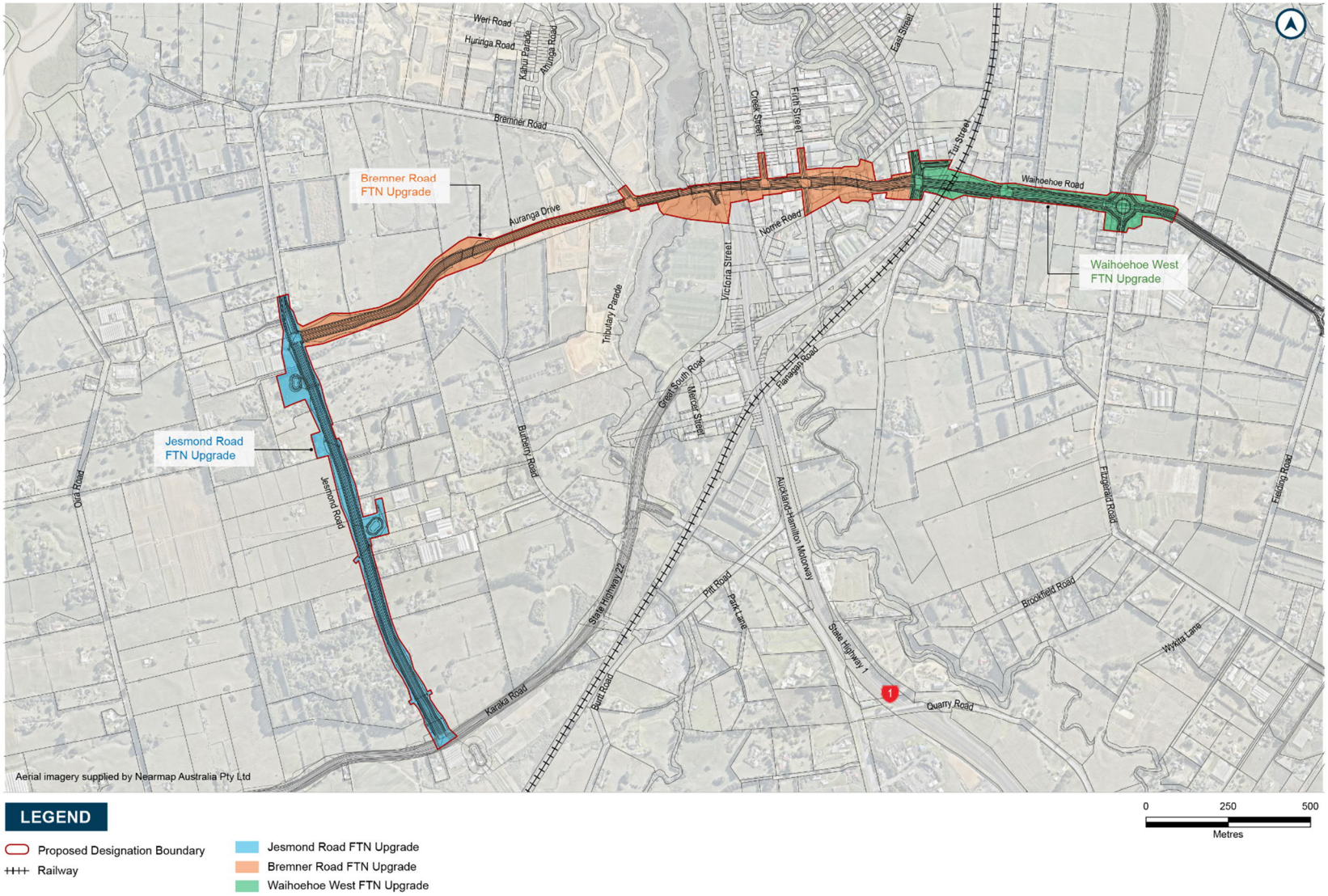


Figure 6-1 Overview of NoR D2

6.1.1 Jesmond Road FTN Upgrade Section

6.1.1.1 Section Overview

The Jesmond Road corridor provides greater accessibility via a north-south link that connects Bremner Road to the proposed Drury West Station and town centre, forming a key public transport and active mode spine through Drury West. An overview of the proposed design is provided in Figure 6-2.

In addition to those listed above, the key features of the Jesmond Road section include:

- Signalised intersections at SH22 and the new Jesmond to Bremner Link
- New and extended pipe culverts for cross drainage and managing overland flow across the corridor
- Two stormwater wetlands

Figure 6-2 Overview of Jesmond Road FTN Upgrade Section

6.1.1.2 Specific Features of this section

Stormwater catchments and features are shown on the layout plan for NoR D2 in Appendix 1. Stormwater will be managed in five catchments:

- Catchment 1 combines with flow from a catchment from the SH22 transport corridor, is treated and attenuated for 100 year ARI rainfall events in SH22's Wetland 2 and then discharges into an existing overland flow path south of SH22.
- Catchments 2 and 3 are treated and attenuated for 100 year ARI rainfall events in Wetland 1 and discharges into an existing overland flow path towards the un-named stream.
- Catchment 4 is treated, and if required, attenuated for 100 year ARI rainfall events in Wetland 2 into the un-named stream.
- Catchment 5 is smaller than 5000 m² and it is proposed that the runoff discharges into the existing swales. There are no signs of existing flooding downstream therefore no flood mitigation was allowed for.

The proposed transport corridor is designed to follow the existing ground level as far as possible while it crosses a few overland flow paths. The longitudinal slopes range between 0.5% and 3% which allows for enough gradient to drain stormwater runoff from the transport corridor via catchpits into an underground pipe system.

The total catchment sizes summarized in Table 6-1 include both the impervious and pervious areas for that catchment.

Table 6-1: Jesmond Road FTN Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management	Attenuation volume provided	Size of wetland permanent water	Discharge point location
1	chainage 2000- 2360. (low point at chainage 2140) plus, SH 22 catchment between chainage 2900-3480	10 800 m² + 22 800 m²	SH22 Wetland 2 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year rainfall event	1 058 m³	668 m³	Unnamed stream at 110 Karaka Road, Drury
2	chainage 2360- 2860 (low point at chainage 2680)	15 000 m²	Wetland 1 for quality treatment, retention and detention, and flood mitigation	1 254 m³	459 m³	Unnamed stream at 137 Jesmond Road, Drury
3	chainage 2860-3080	6 600 m²				

Road Catchment	Catchment Chainages	Total Catchment size	SW Management	Attenuation volume provided	Size of wetland permanent water	Discharge point location
	(low point at chainage 2980)		for the 10 and 100 year event			
4	chainage 3080-3400 (low point at chainage 3160)	9 600 m^2	Wetland 2 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 ARI rainfall event	366 m^3	204 m^3	Un-named stream at 221 Jesmond Road, Drury
5	chainage 3400-3560 (low point at chainage 3560)	4 800 m^2	No attenuation. Stormwater treatment within corridor	n/a	n/a	Discharge into existing swales at chainage 3560m

The existing cross drainage for this transport corridor consists of several culvert crossings. It is proposed that these will either be extended or be replaced with bigger culverts for more flow capacity. The existing and modelled cross drainage is summarized in Table 6-2. The type and size of cross drainage structures are not fixed and will continue to be assessed through subsequent consenting and design phases.

Table 6-2: Jesmond Road FTN Upgrade cross drainage characteristics

Chainage	Upstream catchment	Existing Cross drainage	Modelled Cross drainage
chainage 2080	1.79 ha	225mm dia. culvert	225mm dia. culvert with extensions on both sides
chainage 2160	10.51 ha	900mm dia. culvert	900mm dia. culvert with extensions on both sides
chainage 2630	37.82 ha	450mm dia. culvert connecting to pipe running underground	450mm dia. culvert with extensions at the inlet side
chainage 3000	To be confirmed	300mm dia. Culvert	300mm dia. culvert with extensions on both sides
chainage 3160	10.01 ha	300mm dia. culvert	300mm dia. culvert with extensions on both sides
chainage 3320; across the Jesmond / Bremner Road intersection	1.05 ha	n/a	450mm dia. culvert

6.1.2 Bremner Road FTN Upgrade Section

6.1.2.1 Section Overview

The Bremner Road FTN Upgrade section extends from Jesmond Road in the west, approximately 1.98km to the end of Norrie Road in the east. This section involves the construction of a new road from Jesmond Road to the existing Bremner Road referred to as the "Jesmond to Bremner Link" and widening, and direct connection via a new bridge over Hingaia Stream, of Bremner Road and Norrie Road to enable the four-lane FTN arterial. The functional intent of this section provides greater east-west accessibility that connects Jesmond Road to Great South Road and town centre, forming a key public transport and active mode spine. An overview of the concept design is provided in Figure 6-3.

In addition to those listed above, the key features of the Bremner Road FTN Upgrade section include:

- Signalised intersections on Bremner Road with Auranga Road 1, Creek Street and Firth Street
- Between Jesmond and Bremner Roads (Jesmond to Bremner Link):
    - A new road from Jesmond Road to an unnamed stream (chainage 600m) at the Auranga Development.
    - Forming of two additional lanes for the FTN within the Auranga "Road 1" from the unnamed stream to Bremner Road)
- A new bridge over an unnamed stream within the Jesmond to Bremner Link
- Widening / duplication of the two existing bridges crossing Ngakoroa Stream and SH1. These two bridges are proposed to be reconstructed in the near future as part of the SH1 widening by the Papakura to Drury South Waka Kotahi project which is a part of the New Zealand Upgrade Programme
- A new bridge connection from Bremner Road to Norrie Road across Hingaia Stream
- Removal of Norrie Road Bridge and closure of Norrie Road west
- Removal of access to Bremner Road from Creek Street (south)

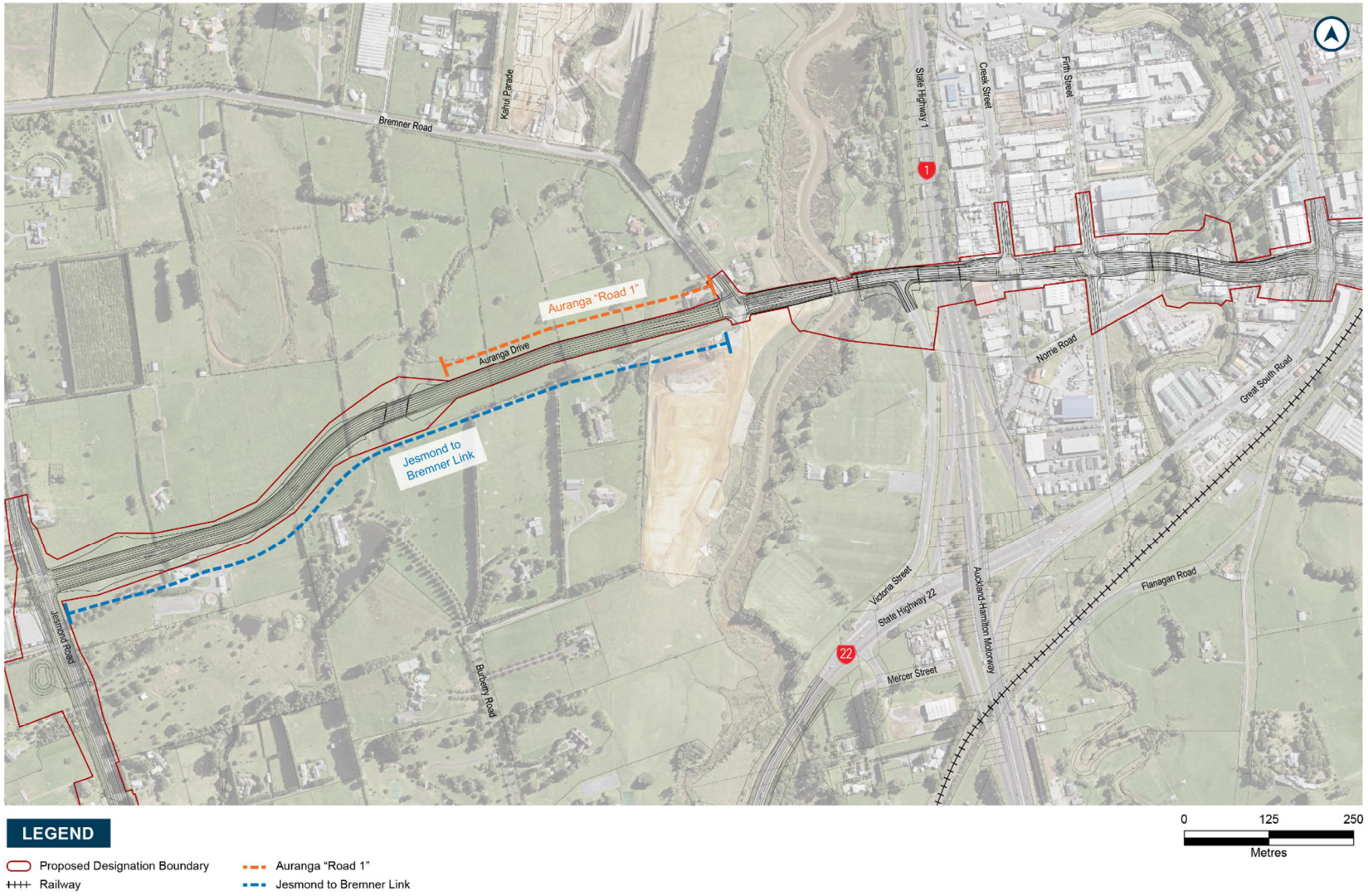


Figure 6-3: Overview of the Bremner Road FTN Upgrade Section

6.1.2.2 Specific Features of this section

Stormwater catchments and features are shown on the layout plan for NoR D2 in Appendix 1.

Four sub-catchments will be created. Runoff from catchment 1 is collected at a low point (chainage 360m) and conveyed via a pipe system to discharge into the un-named stream at chainage 560m. Runoff from the other three catchments are collected at their respective low points and discharged into either the Ngakoroa Stream or Hingaia Stream.

The proposed transport corridor is designed to follow the existing ground level as far as possible while it crosses Ngakoroa Stream, Hingaia Stream and a few overland flow paths. The longitudinal slopes range between 0.5% and 6% which allows for enough gradient to drain stormwater runoff from the transport corridor via catchpits into an underground pipe system. New/replacement bridges over the Ngakoroa and Hingaia streams are proposed.

The transport corridor lies within the lower third of the stormwater catchment and doesn't therefore require any flood mitigation. Stormwater management devices within the corridor are proposed for retention/detention and water quality treatment. The total catchment sizes summarized in Table 6-3 includes both the impervious and pervious areas for that sub-catchment. Discharge locations for road catchment 1 and 2 will be confirmed at detailed design to integrate with future urban development.

Table 6-3: Bremner Road FTN Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management type	Attenuation volume provided	Size of wetland permanent water	Discharge point location
1	chainage 0-800 (low point at chainage 360 and chainage 620)	29 370 m²	Stormwater management within the corridor for detention/ retention and quality treatment	n/a	n/a	Potential location at an un-named stream at chainage 640 Bremner Road, Drury
2	chainage 800-1440 (low point at chainage 1120)	19 200 m²	Stormwater management within the corridor for detention/ retention and quality treatment	n/a	n/a	Potential location at Ngakoroa Stream at ESPLND RES 109 Bremner Road, Drury
3	chainage 1440-1760 (low point at chainage 1660)	9 600 m²	Stormwater management within the corridor for detention/ retention and	n/a	n/a	Hingaia Stream at 41R Firth Street, Drury

Road Catchment	Catchment Chainages	Total Catchment size	SW Management type	Attenuation volume provided	Size of wetland permanent water	Discharge point location
			quality treatment			
4	chainage 1760- 2000 (low point at chainage 1860)	9 600 m²	Stormwater management within the corridor for detention/ retention and quality treatment	n/a	n/a	Hingaia Stream at 41R Firth Street, Drury

A potential set of cross drainage structures for this transport corridor are used to assess the potential flooding effects and are summarized in Table 6-4. The culvert crossings at chainages 830 and 980m are not shown as they are to be designed and constructed by the Auranga development prior to implementation of the NoR. Crossings in the urbanised area include a new/replacement bridge over the Ngakoroa Stream and a new bridge over Hingaia Stream to replace the Norrie Road Bridge. Both a bridge and a culvert were assessed for cross drainage at chainage 600m. The type and size of cross drainage structures are not fixed and will continue to be assessed through subsequent consenting and design phases.

Table 6-4: Bremner Road FTN Upgrade cross drainage characteristics

Chainage	Upstream catchment (ha)	Existing Cross Drainage	Existing Bridge Levels (RL)	Modelled Cross Drainage	Modelled Bridge Levels (RL)
Chainage 600	111 ha	n/a	Ground level 10.66m	2700mm dia. culvert BRE 01 option Bridge option	Bridge soffit level at: 10.39m
Chainage 1300	3830 ha	Ngakoroa Stream Bridge, 29m long	Bridge soffit level 3.4m	Ngakoroa Stream Bridge, two-span, 40m long	Bridge deck at 5.73 at chainage 200 on Aurecon design. Approx. bridge beam soffit 3.8m
Chainage 1760	5498 ha	Norrie Road Bridge, 30m approx.	Bridge top level 6.18m	Hingaia Stream Bridge, two-span, 70m long (0.6m freeboard)	Bridge beam soffit level at 8.85m

6.1.3 Waihoehoe Road West FTN Upgrade Section

6.1.3.1 Section Overview

The Waihoehoe Road West FTN Upgrade section extends from Great South Road in the west, approximately 800m east to just past Fitzgerald Road in the east and involves widening the existing two-lane rural road to enable the four-lane FTN arterial. The functional intent for the section provides a strategic east-west link between strategic north-south and east-west corridors (Norrie Road, Great South Road and the proposed Ōpāheke N-S FTN Arterial (NoR D4)) that connects Waihoehoe Road to the Drury Central Station (and associated park and ride facilities) and town centre, forming a key public transport and active mode spine through Drury West. An overview of the concept design is provided in Figure 6-4.

Figure 6-4 Overview of Waihoehoe Road West FTN Upgrade Section

In addition to those listed above, the key features of the Waihoehoe Road West FTN Upgrade section include:

- Realignment of Tui Street to Great South Road
- Upgraded and signalised intersection at Great South Road
- Reconstruction of the bridge crossing the NIMT rail line
- Relocation of the Waikato 1 watermain. The point of re-location to be agreed with Watercare at future detailed design.

6.1.3.2 Specific Features of this section

Stormwater catchments and features are shown on the layout plan for NoR D2 in Appendix 1.

Two road sub-catchments are created. The sub-catchment between chainage 0m-100m drains away from the Project area towards the Great South Road intersection and will connect to a network there. A catchment from Waihoehoe Road East (NoR D3) between chainage 620m - 960m drains towards, and combines with, Waihoehoe Road West catchment 2 and discharges into an existing overland flow path. Further work is proposed to integrate the discharges with the adjacent future urban development and of the NZUP Drury central rail station at the detailed design phase.

The proposed transport corridor is designed to follow the existing ground level as far as possible with longitudinal slopes ranging between 1% and 6%. The slopes allow for enough gradient to drain stormwater runoff from the transport corridor via swales or catchpits into an underground pipe system.

The transport corridor lies within the lower third of the Hingaia stormwater catchment and does not require any flood mitigation. The total catchment size summarized in Table 6-5 includes both the impervious and pervious areas for the sub-catchment.

Table 6-5: Waihoehoe Road West FTN Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management Device type	Discharge point location
1	chainage 0-100 (low point at chainage 0)	3 000 m²	n/a	Great South Road existing drainage network
2	chainage 100-800 (low point at chainage 240), plus Waihoehoe East between chainage 800-960	21 00 m² + 3 945 m²	No attenuation required.	Location TBC at detailed design to integrate with future urban development

The transport corridor lies on the ridge between the Ōtūwairoa and Hingaia catchments with no existing or proposed cross drainage.

6.2 Existing and Likely Future Environment

6.2.1 Jesmond Road FTN Upgrade section

The existing land use along Jesmond Road is rural. Several overland flow paths and a tributary of the Ngakoroa Stream cross the road by means of culverts and discharge towards the Drury Creek.

The current zoning in the AUPOIP is Future Urban and Residential – Mixed Housing Urban. With reference to the Auckland Council Drury-Ōpāheke Structure plan the future land use for the FUZ is proposed to be urban, likely consisting of Terrace Housing and Apartment Buildings, Local Centre and Mixed Housing Urban/Suburban. Permanent and intermittent streams with a 20 m riparian margin and flood plains are also included in the Drury-Ōpāheke Structure plan.

Drury 1 precinct (Auranga Development) adjacent to the north east of the existing road has commenced development and was extended through Private Plan Change 6 (Auranga B1).

Existing flood prone areas from Auckland GeoMaps are evident where overland flow paths and streams traverse the road. The 100 year ARI flood maps from the latest Auckland Ngakoroa catchment model with MPD and existing terrain show flooding at the culvert crossings and flooding of properties at; 64, 119, 123, 125 and 131 Jesmond Road.

6.2.2 Bremner Road FTN Upgrade section

Moving west to east, the new section from Jesmond Road to Bremner Road runs through a greenfields rural area with no existing road and then into the Auranga Development. From east of the proposed bridge crossing at chainage 600m, the Auranga Development is forming the full width of the road (28m) which will be upgraded with the additional FTN in the future. At the Ngakoroa Stream land use is open space, then crosses SH1, then a mix of commercial and industrial properties.

The current zoning in the AUPOIP is FUZ, Light Industry/Business, Open Space and the Drury 1 Precinct (Auranga Development) located east of the Ngakoroa Stream. The current open space (Drury Sports Complex) will have a low likelihood of change. Flood plain controls are also included in the Drury-Ōpāheke Structure plan.

The existing 100 year ARI flood maps from the latest Auckland Ngakoroa catchment model with Maximum Probable Development and existing terrain show flooding at the new potential major culvert / bridge crossing (chainage 600m), overtopping of the Ngakoroa bridge and overtopping of the existing Norrie Road Bridge that extends into Firth Street and surrounding properties.

Earthworks for development within the FUZ upstream of the greenfields section of the Bremner corridor alignment will change catchment hydrology, the terrain and building and property types that are potentially exposed to flooding around chainage 600m. The assessment has therefore considered specific effects on existing properties and more generally considered effects on potential future development. It is expected that coordination and integration of the corridor design with FUZ development will be required to confirm and address potential future effects.

6.2.3 Waihoehoe Road West FTN Upgrade section

The existing land use along the Waihoehoe Road West FTN Upgrade section lies within a rural area and a business zone area surrounding the intersection with Great South Road. The transport corridor lies on a gentle catchment ridgeline with several overland flow paths draining either north or south, away from the road. The Drury-Ōpāheke Structure plan and the AUPOIP, identifies the land as FUZ, Business – Light Industry Zone, Business – Mixed Use Zone and Business – Local Centre Zone.

A flood plain and flood prone area from Auckland GeoMaps is evident south of the transport corridor on an overland flow path at 67 and 71 Waihoehoe Road.

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

6.3.1 Jesmond Road FTN Upgrade section

This section of the report assesses the impact during the construction and operational phases on the flood extents and changes in water levels caused by the upgraded transport corridor. A 2D flood model for the Ngakoroa catchment has been generated for the pre- and post-project development scenarios for the 10 year and 100 year ARI rainfall events. Table 6-6 summarizes the existing (pre-project development) and future (post-project development) flood levels at key culvert crossings.

Table 6-6: Jesmond Road FTN Upgrade existing and future flood levels at key crossings

Chainage	Existing Cross drainage	Existing flood level (MPD + CC) (RL)	Modelled Cross drainage	Modelled flood level (MPD + CC) (RL)
chainage 2080	225mm dia. culvert existing ground level, ch 2080 RL 16.43m	10 year ARI rainfall event: 16.84m upstream, 16m downstream	225mm dia. culvert with extensions on both sides Road design level, RL 17.9m	10 year ARI rainfall event: 17.43m upstream, 16.25m down-stream
		100 year ARI rainfall event: 16.84m upstream, 16.0m down-stream		100 year ARI rainfall event: 17.50m upstream, 16.25m down-stream
chainage 2160	900mm dia. culvert existing ground ch 2160, level RL 15.53m	10 year ARI event: 16.68m upstream, 14.75m down-stream	900mm dia. culvert with extensions on both sides Road design level, RL 16.8m	10 year ARI event: 16.88m upstream, 14.85m down-stream
		100 year ARI event: 16.74m upstream, 14.81m downstream		100 year ARI event: 16.95m upstream, 14.89m down-stream
chainage 2630	450mm dia. culvert connecting to pipe running under-ground existing road level RL ±16.0	10 year ARI rainfall event: 16.59m upstream, 16.49m down-stream	450mm dia. culvert with extensions at the inlet side Road design level, RL 16.6m	10 year ARI rainfall event: 16.88m upstream, 16.49m down-stream
		100 year ARI rainfall event: 16.72m upstream, 16.59m down-stream		100 year ARI rainfall event: 16.99m upstream, 16.56m down-stream

Chainage	Existing Cross drainage	Existing flood level (MPD + CC) (RL)	Modelled Cross drainage	Modelled flood level (MPD + CC) (RL)
chainage 3000	300mm dia. culvert crossing chainage 2980 existing road level RL 17.20	10 year ARI rainfall event: 17.33m downstream	Culvert not modelled Road design level, RL 17.7m	10 year ARI rainfall event: 17.41m downstream
		100 year ARI rainfall event: 17.35m downstream		100 year ARI rainfall event: 17.44m downstream

6.3.1.1 Positive Effects

The proposed upgrade of Jesmond Road provides the opportunity to upgrade existing culvert capacities where the flood model identifies existing and/or future flooding of properties. Overland flow currently crosses Jesmond Road in several locations and it is expected that the works will include upgrades to better manage overland flow across the road.

6.3.1.2 Assessment of Construction Effects

Three new wetlands are proposed, three new outlets from the wetlands, one new culvert crossing and five existing culvert crossings requiring extension to accommodate the transport corridor widening.

SH22 Wetland 1 at chainage 1900 on SH22 is outside of flood plain and overland flow paths.

Jesmond Wetland 1 at chainage 2700 is located downstream of the upgrade transport corridor, east of Jesmond Road, adjacent to the un-named stream within the project area. The proposed wetland encroaches into the existing flood plain area and is in close proximity to the main overland flow path. This area is prone to flooding during larger rainfall events and the wetland footprint may obstruct and divert flow which may exacerbate an existing flooding problem at 125 Jesmond Road.

Wetland 2 at chainage 3160 will be constructed upstream of the transport corridor, west of Jesmond Road and is located outside of the flood plains. It is in close proximity to two overland flow paths and a modified stream.

The main risks associated with flooding during construction will be a combination of insufficient temporary drainage or blockage of overland flows close to adjacent buildings, namely:

- Earthworks associated with raising the road low point at about chainage 2100 near 16 Jesmond Road
- Earthworks associated with raising the road low point at about chainage 2700, constructing Jesmond Wetland 1 and insufficient downstream drainage near 125 Jesmond Rd
- Earthworks associated with wetland 2 potentially blocking the overland flow paths at about chainage 3160

A construction yard and stockpile site are proposed on 256 Jesmond Road which is outside flood plains and major overland flow paths. It therefore does not present increased flood hazard risks.

Various culverts need to be installed or upgraded. There could be increased flood levels or new flow paths created during construction if adequate flow diversions are not provided.

Overall the potential flooding effects are considered to be relatively minor, except where there are nearby habitable buildings close to existing flooding at 125 Jesmond Rd.

6.3.1.3 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Stormwater Management Wetlands

Jesmond Wetland 1 will require a diversion drain constructed around the area of works suitable to protect the existing house at 125 Jesmond Rd. It is recommended that the outlet to the overland flow path and / or lowering the access to the property behind 131 Jesmond Ave is carried out as a first stage of construction work to reduce the construction phase flood risk.

The outlet from Wetland 2 is upstream of an existing culvert crossing which may require upgrading (and possibly extending to the downstream stream head) - should be completed in the initial phases of construction, prior to construction of the wetland, so as not to increase flood hazard risks.

Clean water diversion controls and temporary drainage will be required in various other areas to prevent overland flow encroaching into the works area or backing up and affecting existing properties.

Culverts

Due to the existing culverts draining small rural areas, baseflow rates will be relatively small and the risk of flooding is considered low provided adequate diversions or over-pumping is provided and works are carried out in the summer earthworks season.

The proposed new culvert crossing diagonally though Jesmond and Bremner Road will be constructed completely offline. It consists of a small upper catchment and therefore temporary damning will be suitable, without over pumping, to ensure the area of works remains dry during construction. The outlet for this crossing is located adjacent to the proposed location for the construction yard and new fill embankment. Once the crossing is opened, a clean water diversion channel should be incorporated to allow for flow to be directed to the completed downstream culvert crossing near Wetland 2 (thereby avoiding works associated with Wetland 2).

The working area around the culverts will be dependent on its size, location and volume of water to be managed/diverted. Where no diversion is required and works are carried out offline, ±6m working clearance will be required to accommodate access and materials. For larger diameter pipes within the overland flow path and requiring diversion, ±20 m beyond the permanent upstream extents and ±15 m beyond the downstream extents should be allowed for.

Mitigation

Flood hazards for the construction phase should be specifically addressed in a CEMP. Key issues to consider are;

- an overland flow path and site levels around Wetland 1 to manage flood risk at 125 Jesmond Road during construction
- siting construction yards and stockpiles outside the flood plain
- 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 high flow events, and
- methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

6.3.1.4 Assessment of Operational Effects

This assessment of effects refers to the flood model results and considers the flooding extents at existing and new culvert crossings. The assessment also considers the extents of flooding on existing properties due to the project. The following key areas are identified and described in more detail in the sections below:

- Existing culvert crossings at chainage 2080 (near 16 Jesmond Road) and chainage 2160 (near 64 Jesmond Road)
- Existing culvert crossing at chainage 2630 (near 125 Jesmond Road)
- Inferred existing culvert crossing at chainage 3000 (near 224 Jesmond Road)

6.3.1.4.1 Crossing at chainage 2080 and 2160

The results for the 100 year ARI pre-project development scenario indicate that the water level upstream of the crossing at chainage 2080m (JES_02) is 16.87 m and 16.74 m upstream of the crossing at chainage 2160m (JES_03). The culvert invert levels and sizes remain the same for the post-project development scenario. The results for the 100 year ARI post-project development scenario for culverts JES_02 and JES_03 indicate that the water levels upstream increase to 17.50 m (+0.56m at point B below) and 16.95 m (+0.21m at point A below) respectively. The depth difference map shown in Figure 6-5 also shows the reduction and increase of water depths. The increases in water levels are due to raising the vertical alignment of the road and the existing overland flow path having to build up more depth upstream before it overtops the road.

The increase in water level could affect development potential as both sides of Jesmond Road are zoned FUZ and a range of residential typologies are expected in the future.

The main potential effect of the road upgrade is to change the overland flow running across the road due to the increased height of the road at the sag point on the vertical transport corridor, which then changes the location of the overland flow on the downstream side. The water depth increase upstream is mostly around the area upstream of culvert JES_02 (16 Jesmond Road), where a potential existing natural wetland has been identified (refer Point B in Figure 6-5). This area however, already floods and its future development potential is uncertain. The adjacent 64 Jesmond Road site may be partly affected by local flooding and some minor increases in surface ponding depth are identified upstream of culvert JES_03 (refer Point A in Figure 6-5). However, these are on the property's carpark area away from the existing café on site and could likely be regraded as part of any redevelopment. Overland flow may run across the road near here and therefore a pipe upgrade could be considered for managing flood hazard for future road users.

A flood prone area upstream of the culvert inlet at chainage 2080 may be exacerbated along with an increase in the flood level on the upstream area which has been identified as a natural wetland. In the future development scenario, there is potential for blockages at the inlet to cause flooding but given that the flood prone area is also a natural wetland and subject to flooding, the development potential may be limited and this is considered a minimal risk.

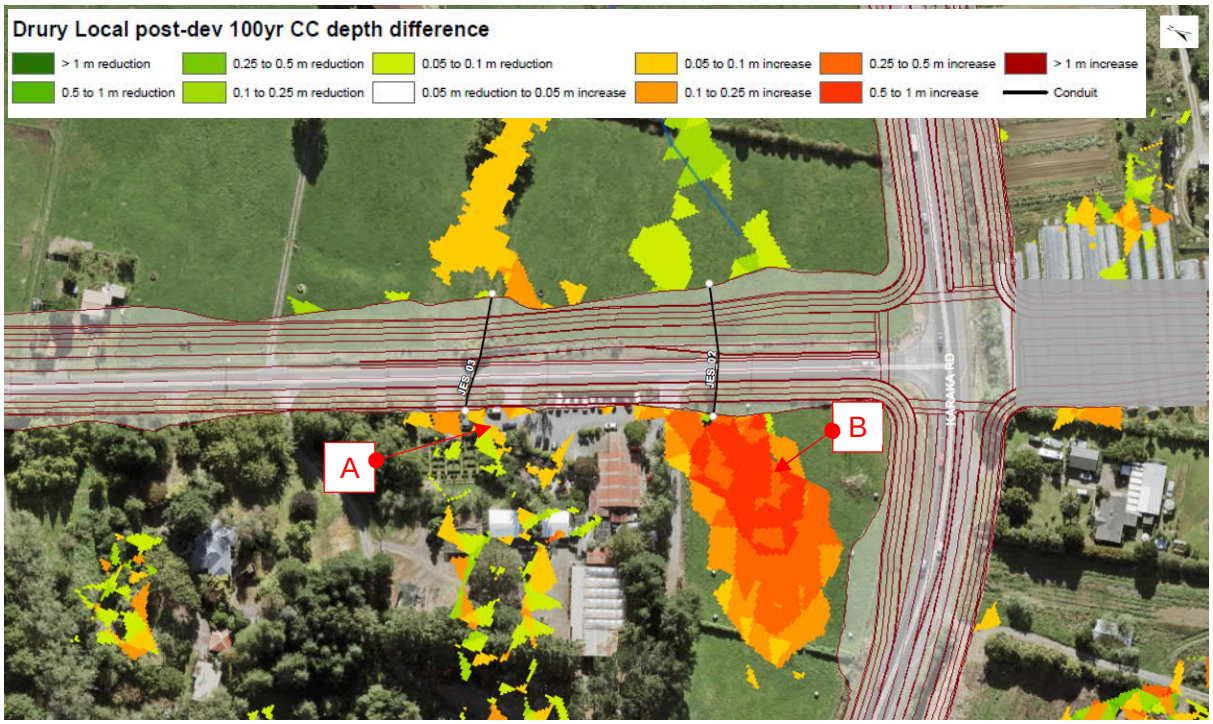


Figure 6-5: 100 Year difference map for post- minus pre-project development at Jesmond Road and existing crossings at chainage 2080 (JES-02) and at chainage 2160 (JES-03)

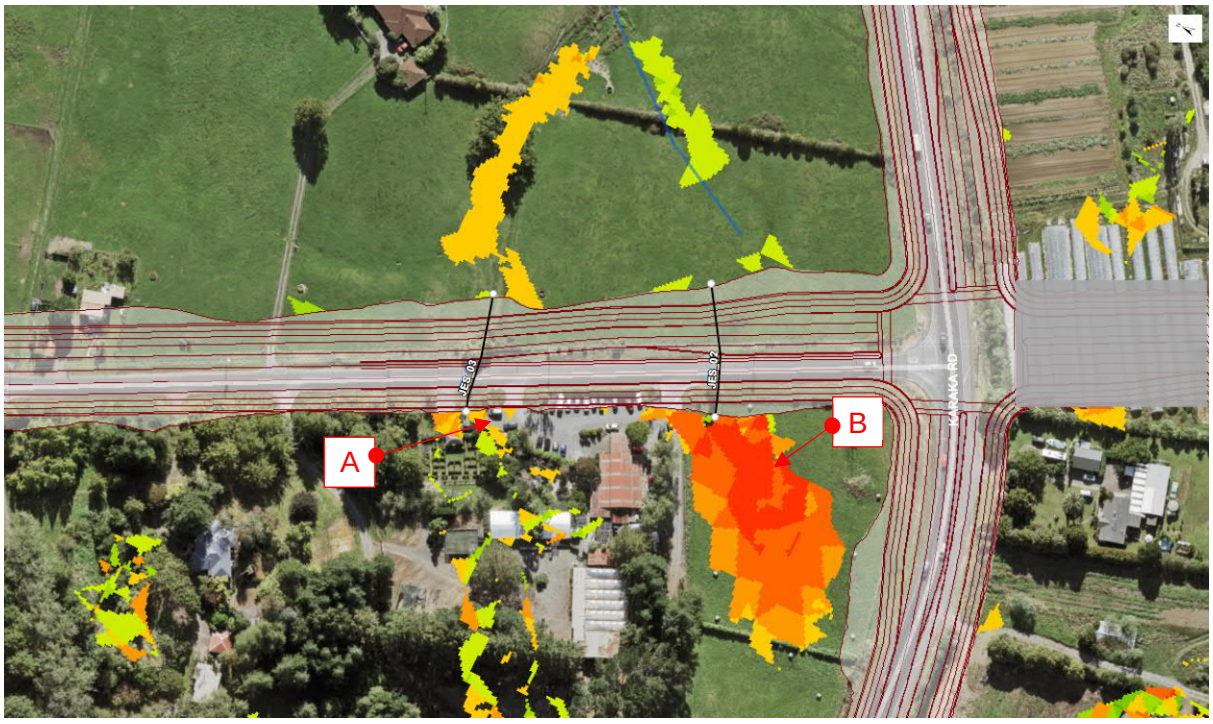


Figure 6-6: 10 Year difference map for post- minus pre-project development at Jesmond Road and existing crossing at chainage 2080 (JES-02) and at chainage 2160 (JES-03)

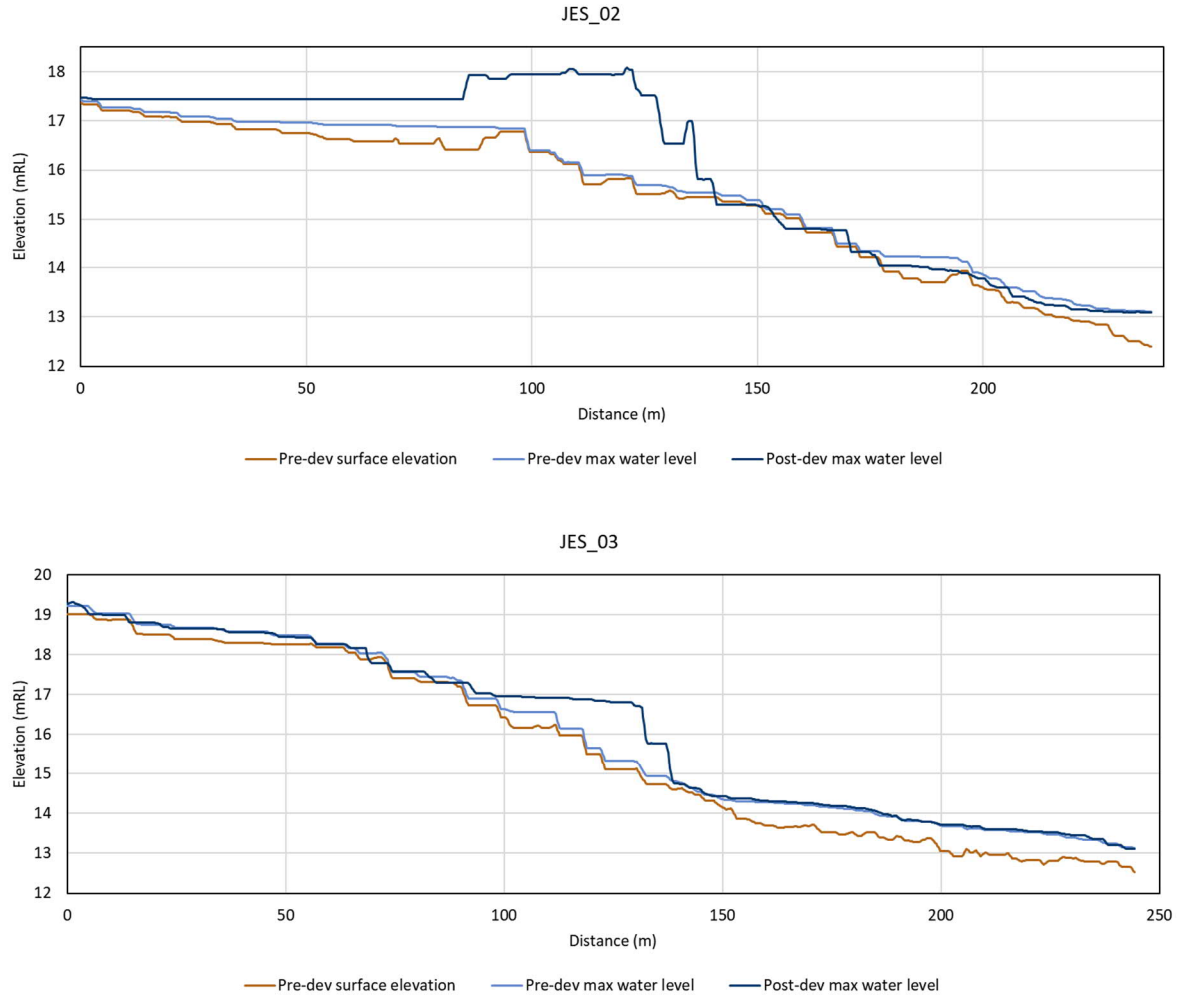


Figure 6-7: Hydraulic grade line at Jesmond Road and existing crossing at chainage 2000 (JES-02) and at chainage 2160 (JES-03)

6.3.1.4.2 Crossing at chainage 2630

The area downstream of chainage 2630 has existing flooding. 125 and 119 Jesmond Road front directly on to Jesmond Road and are flood prone because there are no defined overland flow paths that would allow flood water from the road to escape easily to the stream channel to the west. This situation appears to be the result of driveways for 123 and 131 Jesmond Road having relatively high levels compared to the surrounding ground with poorly defined low points.

The results for the 100 year pre-project development scenario indicate that the water level upstream of the crossing at chainage 2630 (JES_04) is 16.73 m. The modelled culvert invert levels and sizes remain the same for the post-project development scenario. The results for the 100 year ARI post-project development upstream of JES_04 show an increase in water levels to 16.99 m (+0.26m at point E below). The depth difference map shown in Figure 6-8 also demonstrates the reduction and changes in water depths (note that overland flow across the road is not shown).

The main potential effect of the road upgrade is to concentrate the overland flow running across the road due to the increased height of the road and movement of the sag point on the vertical transport

corridor. There is a water depth increase upstream - mostly around the area upstream of culvert JES 04 (opposite 119 Jesmond Road) and slightly to the east on the driveway of 84 Jesmond Road. Downstream of the road, there is a decrease in flood levels on 125 Jesmond Road and a local change in the area of flooding and overland flow onto 119 Jesmond Road.

Point C shows a decrease in flood level due to restricting the flow upstream. However, Jesmond wetland 1 is proposed to be sited at 131 Jesmond Road and given that the wetland is located within the area of shallow existing flooding (and if it is constructed above ground level), it may have some effect by diverting overland flow.

This area is zoned for future urban development. The reduction in water levels downstream of the crossing will have a positive impact on 125 Jesmond Road (Point C). The increase in flood height upstream of the culvert (refer points D and E on Figure 6-8 below) may affect the extent of developable land at these points. There will be overtopping of the road if there is insufficient pipe capacity or a culvert blockage occurs – which may have an effect on the flood risk on buildings developed in these areas. Mitigation of this is required so that flood effects at 125 Jesmond Road are not exacerbated. It is recommended to; drain water overland from Point D to E, upsize the Jesmond 04 culvert and extend it to the head of the stream, create a formal overland flow path around 125 Jesmond Road and lower the driveway at 131 Jesmond Road.

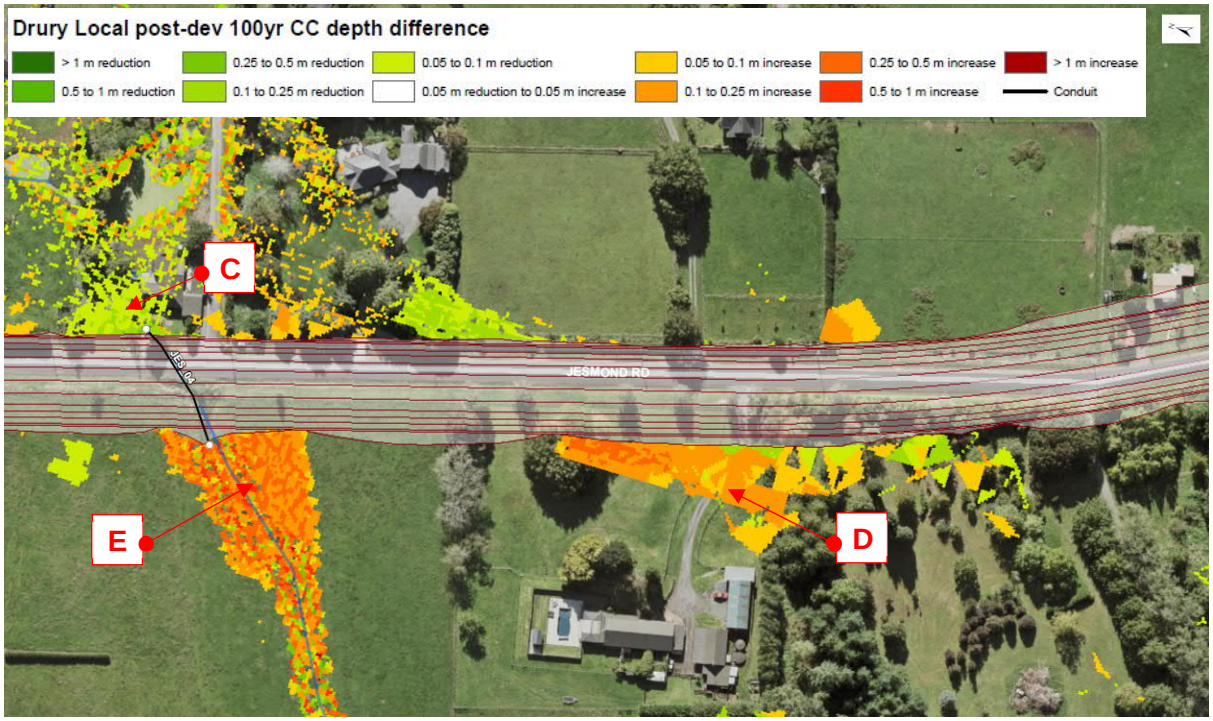


Figure 6-8: 100 Year difference map for post- minus pre-project development at Jesmond Road and unnamed stream at chainage 2630 (JES-04)

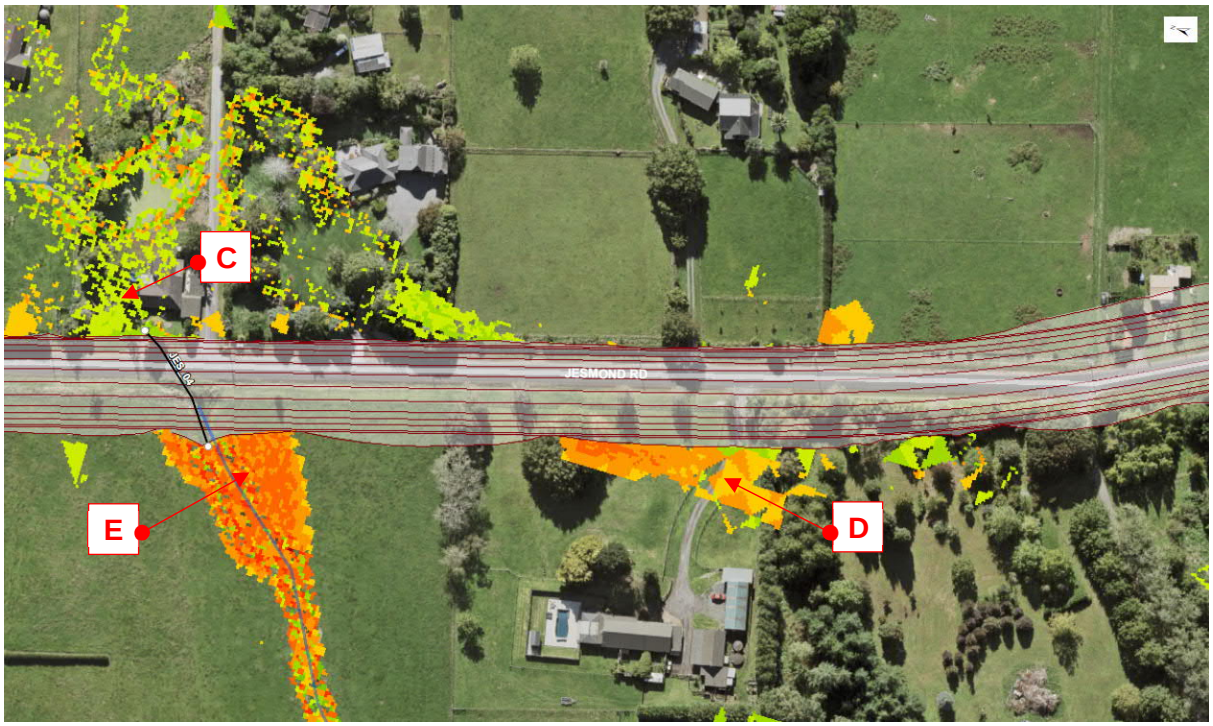


Figure 6-9: 10 Year difference map for post- minus pre-project development at Jesmond Road and unnamed stream at chainage 2630 (JES-04)

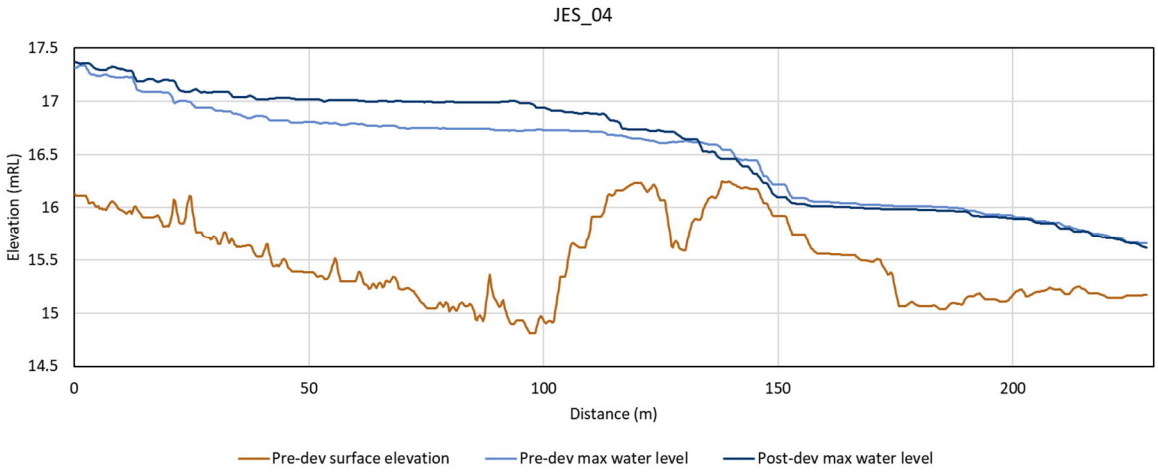


Figure 6-10: Hydraulic grade line at Jesmond Road and unnamed stream at chainage 2630 (JES-04)

6.3.1.4.3 Crossing at chainage 3000

The depth difference map shown in Figure 6-11 shows a local increase of water depths upstream and downstream of the road upgrade. The post-project development water levels have changed location slightly on the property's driveway at 201 Jesmond Road on the downstream side of the road (refer Point F in Figure 6-11).

Again, these local increases in flooding upstream are due to a slight increase in the design of the road height at the sag point which then redirects the flow slightly on the downstream side of the road. The increase in flood level on the upstream side at 188 Jesmond Road is confined to the lawn in the north west corner and contours show the house is elevated at least 1m above the existing road level. Overland flow across the road and flooding at the inlet could be managed by upgrading the culvert size.

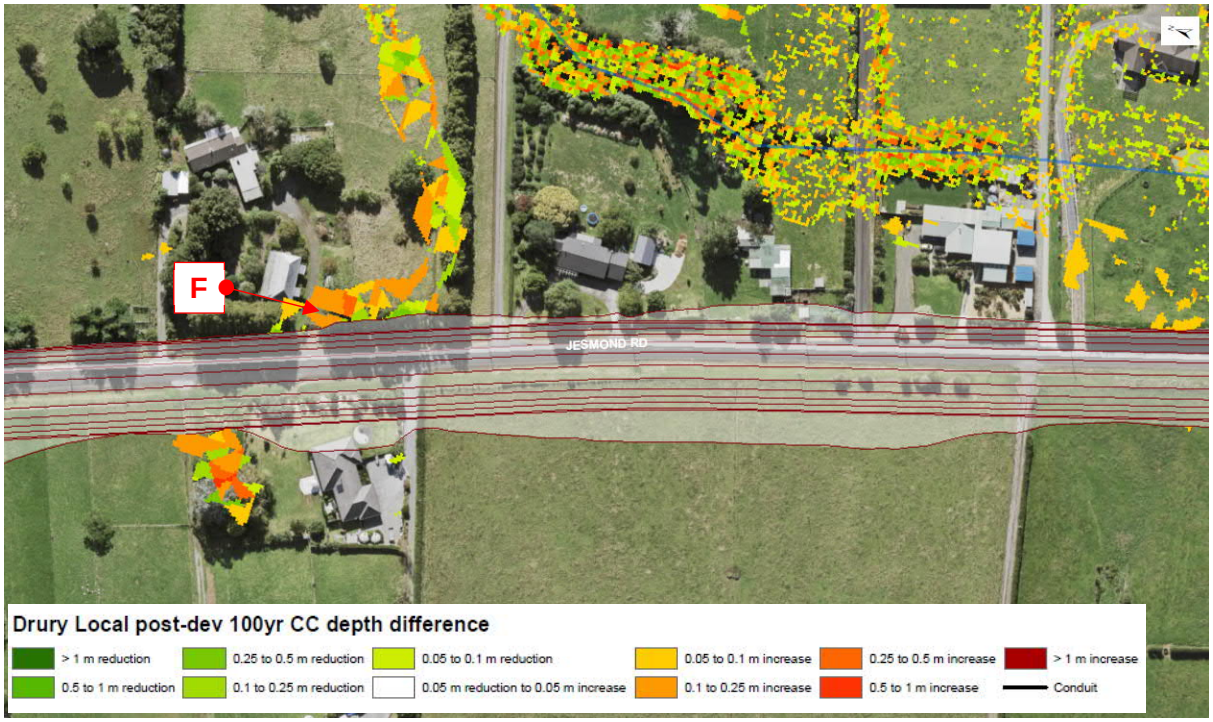


Figure 6-11: 100 Year difference map for post- minus pre-project development at Jesmond Road at chainage 3000

6.3.1.4.4 Property Assessment

According to the Auckland Council Modelling Specification a freeboard of 500 mm should be added on top of the 100 year ARI MPD flood level for habitable floor levels to have adequate freeboard and safe for use. Buildings floors potentially affected by flood hazards are counted either as being below the 100 year flood level or within 500 mm of the 100 year flood level. Driveways and parking areas should be kept safe from flooding with allowable water depths below 150 mm for cars and 300 mm for trucks.

The difference maps above present the post- minus the pre-project development water levels for the 100 year ARI rainfall event. With reference to Figure 6-5, Figure 6-8 and Figure 6-11, the properties where flooding levels have changed due to the potential changes to the road's vertical alignment are listed in Table 6-7. These changes in flood levels are considered potential effects (as the road levels are only preliminary), and there are a number of ways that they can be mitigated.

Table 6-7: Properties potentially at risk of flooding along Jesmond Road and surrounds

Point on difference map	Property address	Affected area	100 Year flood level (RL)	Water level difference for 100 year post minus pre-project development	Assessment
Point A	64 Jesmond Road, Drury	Parking area, no habitable floors. FUZ	Pre-dev: 16.95m Post-dev: 16.74m	+ 0.21m	Increase in flood level 50mm to 500mm; minor effect.
Point B	16 Jesmond Road, Drury	Rural land, no habitable floors. FUZ	Pre-dev: 16.94m Post-dev: 17.50m	+ 0.56m	Due to change in road sag point level,
Point C	119,125, 131 Jesmond Road, Drury	Building / houses. FUZ	Pre-dev: 16.59m Post-dev: 16.56m	- 0.03m	Decrease in flood level at culvert outlet. But note nearby berm levels and wetland require an overland flow path to manage potential effects.
Point D	84 Jesmond Road, Drury	Driveway, house sited at RL 20.5m. FUZ	Pre-dev: 17.63m Post-dev: 17.73m	+ 0.1m	Increase in flood level 50mm to 500mm; minor effect.
Point E	Flooding area in rural land opposite 125 Jesmond Rd	Rural land, no habitable floors. FUZ	Pre-dev: 16.75m Post-dev: 17.0m	+ 0.25m	Increase in flood level 50mm to 500mm; minor effect
Point F	201 Jesmond Road, Drury	Driveway, buildings/houses sited at RL 17.5 to 18.5m. FUZ	Pre-dev: 17.35m Post-dev: 17.44m	+ 0.09m	Increase in flood level 50mm to 500mm; minor effect

6.3.1.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

There are a range of methods available to mitigate the potential flooding effects identified. Slight changes to the vertical alignment of the road design to match existing road levels could be used to lower the water level at the road sag points. Alternatively, culverts under the road could be upsized to cater for 100 year flows and direct them to downstream channels. On the downstream side of the road, open channels can be installed to collect overland flow and direct it to appropriate discharge locations. These are matters that can be addressed at a future stage of design. The risk of flooding from culvert blockage could be addressed within the designation sought through methods such as

overland flow paths, upsizing culverts and secondary inlets and this should be considered further at detailed design.

Wetland 1 at 131 Jesmond Road could obstruct overland flow and exacerbate nearby flooding if it was constructed above existing ground level. Therefore, it is recommended that an overland flow path be excavated from the low point on the transport corridor, past the southern side of the proposed wetland to collect flood water, lower the driveway at 131 Jesmond Road and discharge it to the watercourse channel to the north so as to drop existing flood levels in the area. As the sag point in the road may change, it is also recommended that an open channel be constructed along the frontage of 119 and 125 Jesmond Road to collect overland flow off the road and direct it safely around those two properties to the eastern side of the proposed wetland. A condition should be included within the proposed designation to identify key outcomes to be achieved (that will address the above matters) at the detailed design phase.

6.3.1.6 Summary and Conclusions

The potential construction phase flooding effects are able to be managed and with the proposed Construction Environmental Management Plan taking account of flooding the effects are expected to be minor. Flood hazards for the construction phase should be addressed in the proposed Construction Management Plan. Key issues for the CEMP to consider are;

- siting construction yards and stockpiles outside the flood plain
- staging and programming to carry out work when there is less risk of high flow events, and
- methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

Overall, the Jesmond Road FTN Upgrade could have some effect on flood levels at the sag points where overland flow crosses the road transport corridor. With careful design of road levels and upsizing of culverts, flood levels can be managed to be no worse than they currently are and overland flow across the road removed. Construction of a diversion drain at 119, 125 and 131 Jesmond Road will direct overland flow away from the buildings on site, lower flood levels and improve the existing situation. A condition should be included within the proposed designation to identify key outcomes to be achieved (that will address the above matters) at the detailed design phase.

6.3.2 Bremner Road FTN Upgrade section

This section of the report assesses the impact from construction and operation due to the flood extents and changes in water levels caused by the upgraded and new transport corridor. A 2D flood model for the Ngakoroa and Hingaia catchments have been generated for the pre- and post-project development scenarios for the 10 and 100 year ARI rainfall events. Table 6-8 summarizes the existing (pre-project development) and future (post-project development) flood levels at key stream crossings.

Table 6-8: Bremner Road FTN Upgrade existing and future flood levels at key crossings

Chainage	Existing Cross drainage	Existing Culvert Invert / Bridge Levels (RL)	Existing flood level (MPD + CC) (RL)	Modelled Cross drainage	Modelled Bridge Levels (RL)	Future flood level (MPD + CC) (RL)
Chainage 600	n/a	Ground level at 10.66m	10 year ARI rainfall event: 9.35m upstream, 8.90m downstream	Un-named stream, Bridge structure, single span, 35m long plus stream diversion	Bridge beam soffit: 10.39m Road CL design level 12.61m	10 year ARI rainfall event: 9.84m upstream, 8.90m downstream
			100 year ARI rainfall event: 9.72m upstream, 9.25m downstream			100 year ARI event: 10.13m upstream, 9.25m downstream
Chainage 1300	Ngakoroa Stream bridge structure, three-span, 29m long	Bridge soffit level at 3.4m	10year ARI rainfall event: 4.78m upstream, 4.59m downstream	Ngakoroa Stream Bridge structure, two-span, 40m long	Bridge beam soffit at 4.9m Road CL design level 6.80m	10year ARI rainfall event: 4.65m upstream, 4.60m downstream
			100 year ARI rainfall event: 6.27m upstream, 6.11m downstream			100 year ARI rainfall event: 6.11m upstream, 6.08m downstream
Chainage 1760	Norrie Road Bridge structure	Bridge top level at 6.18m	10year ARI rainfall event: 6.34m upstream, 6.15m downstream	Hingaia Stream Bridge structure, two-span, 70m long	Bridge soffit at 8.85m	10year ARI rainfall event: 6.25m upstream, 6.15m downstream
			100 year ARI rainfall event: 8.20m upstream, 7.74m downstream			100 year ARI rainfall event: 7.79m upstream, 7.72m downstream

6.3.2.1 Positive Effects

The new bridge over Ngakoroa stream decreases the flooding upstream by 0.16m due to its wider span.

The new Hingaia Stream Bridge will provide significantly reduced upstream flood risk and improved freeboard and resilience.

The existing Norrie Road Bridge over Hingaia Stream overtops during a 100 year rainfall event. Existing flood levels upstream of the bridge are about half a metre higher than downstream due to the head losses from the bridge deck obstructing the flow. The existing 100 year ARI flood plain extends to the surrounding properties and Firth Street and floods a number of buildings. Even in the 10 year rainfall event, a number of buildings are flooded. The Bremner Road FTN Upgrade section crosses the Hingaia Stream in a different location which creates the opportunity to design a new bridge above flood levels and allow for a minimum freeboard of 0.6 m between the 100 year flood level and bridge soffit to provide a 100 year ARI level of serviceability to traffic. With the removal of the Norrie Road Bridge flood levels are reduced by 0.34 m upstream and 0.07 m downstream in the 100 year rainfall event, thereby reducing the flood risk to a number of buildings and roads.

Water levels for the Hingaia upstream, at the rail crossing at Flanagan Road, are 9.59 m and 9.49 m for the pre and post-project development scenarios. The new bridge over Hingaia Stream results in a decrease in water depth of 100 mm and therefore has a positive effect on the existing flooding affecting the rail transport corridor.

6.3.2.2 Assessment of Construction Effects

The construction of this section includes, two new outlets to Hingaia Stream and four new bridge crossings (3 x stream, 1 x motorway crossing) and removal of the existing Norrie Road Bridge crossing over the Hingaia Stream. These construction activities will require diversions and flow management to mitigate flood hazard effects.

The new bridges over the unnamed stream, Ngakoroa Stream and Hingaia Stream will likely require temporary staging platforms for piling rigs and cranes to be constructed on the banks and possibly over the stream bed. The existing Norrie Road Bridge will be closed at the beginning of the work and used for construction traffic until the completion of the new Hingaia Stream Bridge.

The main risks associated with flooding during construction will be a combination of insufficient temporary diversions or constriction of stream flows, namely:

- Earthworks associated with creating the new road low point and bridge at about chainage 600
- Earthworks associated with forming the western Ngakoroa Stream Bridge abutments and/or temporary staging causing a constriction to Ngakoroa Stream flows
- Earthworks associated with forming the Hingaia Stream Bridge abutments and/or temporary staging causing a constriction to Hingaia Stream flows, particularly prior to removal of the existing Norrie Road Bridge

Temporary platforms may be constructed on the banks and over the bed using driven steel piles or the existing bridge could be used as a platform. Piling rigs will sit on top of the platforms to construct the bridge piers.

These platforms could cause a constriction to flood flows and cause a backwater effect, raising upstream flood levels. The new Ngakoroa Stream Bridge has an overall span of 40 m and the new Hingaia Stream Bridge has an overall span of 70 m which is long enough to bridge over the stream bed and avoid effects from siting piers on the stream bed and channel. This avoids the potential for diverting flow in the deepest and fastest flowing section of stream, which consequently reduces the risk of erosion and blockage of the main stream flow path during construction.

No properties that may be impacted are identified upstream of the Ngakoroa bridge crossing. Several industrial properties are sited in a flood plain upstream of the Hingaia Stream Bridge crossing. The combination of a temporary constriction at the bridge and an extreme flood means there is conceptually an elevated risk of flooding to those properties for the duration of the temporary works being in place.

A number of construction yards are proposed along the corridor and in general these are outside floodplains so no adverse effects on flooding are expected. A construction yard proposed on the northern side of the Hingaia Stream is within the 100 year flood level, which may cause a constriction to flood flow.

6.3.2.3 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Bridges

Temporary platforms should generally be set back as far as practicable from the stream banks.

Timing construction works during the dry season mitigate potential effects and minimise the potential for flooding and erosion due to increased stream flow around temporary work platforms and piling areas. Staging of earthworks for the abutments and the main bridge span construction should be considered to manage the potential to block flood flows.

Norrie Road Bridge can be closed off to normal traffic flow and serve as continued access for construction vehicle traffic. This will mitigate the need for additional works within the stream for a temporary crossing. However, Norrie Road Bridge should be demolished on completion of works because the flooding benefits will not be realised otherwise.

Stockpiling near the adjacent streams and overland flow paths should be avoided on the nearby flood plains.

Mitigation

Flood hazards should be specifically addressed for the construction phase in a CEMP. Key issues to consider are:

- siting construction yards and stockpiles outside the flood plain
- minimising the physical obstruction to flood flows under the existing bridges from temporary works
- staging and programming to carry out work when there is less risk of high flow events
- staging and programming to provide new drainage prior to raising road design levels and carry out work when there is less risk of high flow events

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

A condition within the proposed designation is recommended to address these matters in the CEMP.

6.3.2.4 Assessment of Operational Effects and Recommended Measures

This assessment of effects refers to the flood model results and considers the flooding extents at bridge structures and any significant areas where the new road embankment encroaches on to existing flood plains. The following key areas are identified and described in more detail in the sections below:

- New bridge crossing at chainage 600
- Bremner / Ngakoroa Stream Bridge
- Bremner / Hingaia Stream Bridge

6.3.2.4.1 Bridge at chainage 600

Flood levels will increase if a new 3.00m dia. culvert is used at the Bremner Road stream crossing at chainage 600. The results for the 100 year ARI pre-project development indicate that the water level at chainage 600m (BRE_01) is 9.72 m upstream of the crossing. Modelling of the culvert indicates an increase in depth of > 0.5m upstream and a reduction of up to 0.5m downstream. A 35m span bridge at 30 degree skew has also been modelled at this location and shows that, provided the stream approach can be diverted slightly on the southern side of the corridor and local drainage for the abutments provided toward the bridge (subject to future regional consent), the effects on the upstream flood levels can be negligible.

One property is adjacent to the existing upstream, with flow passing immediately to the east of the parking area on the property. This property is further upstream than the flood plain created by the proposed road and the flood difference map shows no change to the adjacent flood levels (refer Point B on Figure 6-12).

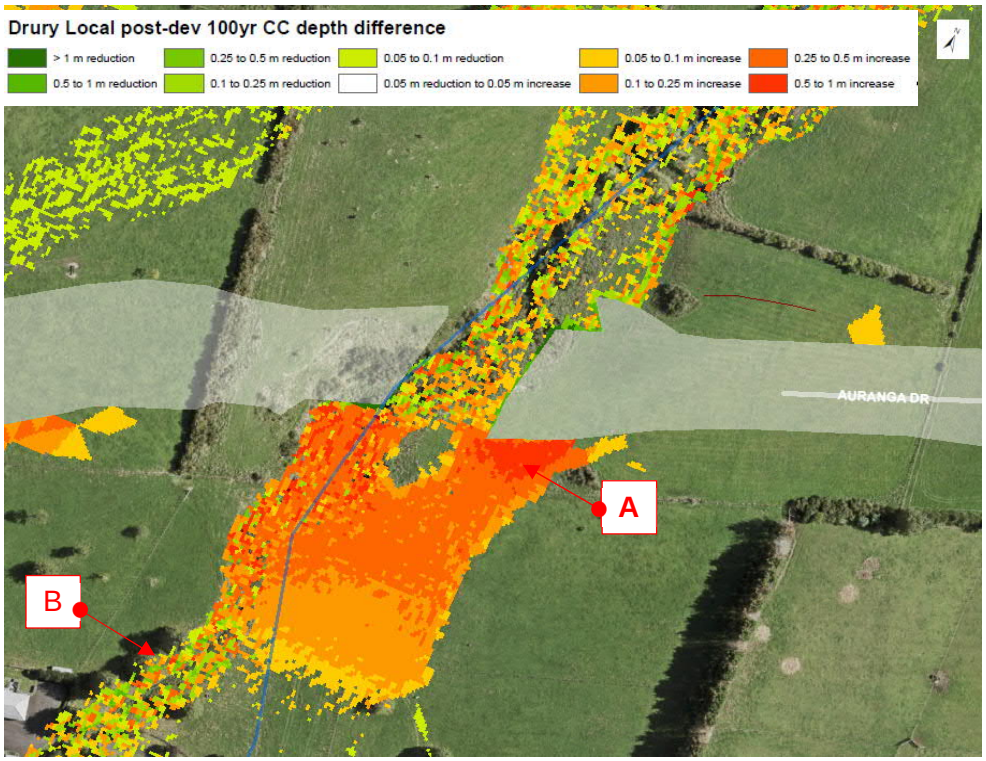


Figure 6-12: 100 Year difference map for post- minus pre-project development at Bremner Road and unnamed stream crossing (bridge at chainage 600)

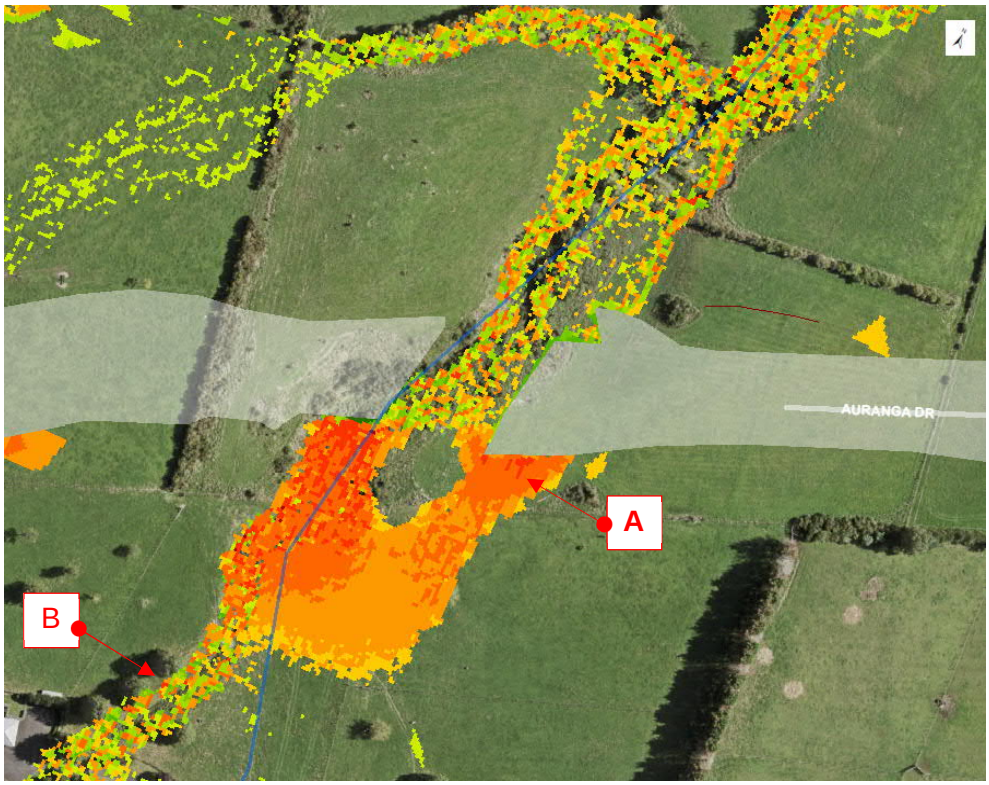


Figure 6-13: 10 Year difference map for post- minus pre-project development at Bremner Road and unnamed stream crossing (bridge at chainage 600)

The new bridge has a 35m single span with abutment walls and 30 degrees skew to realign with the stream. A short distance of the stream will need to be realigned upstream and local drainage channels provided to resolve the upstream headwater formed due to part of the existing channel being obstructed by the proposed embankments.

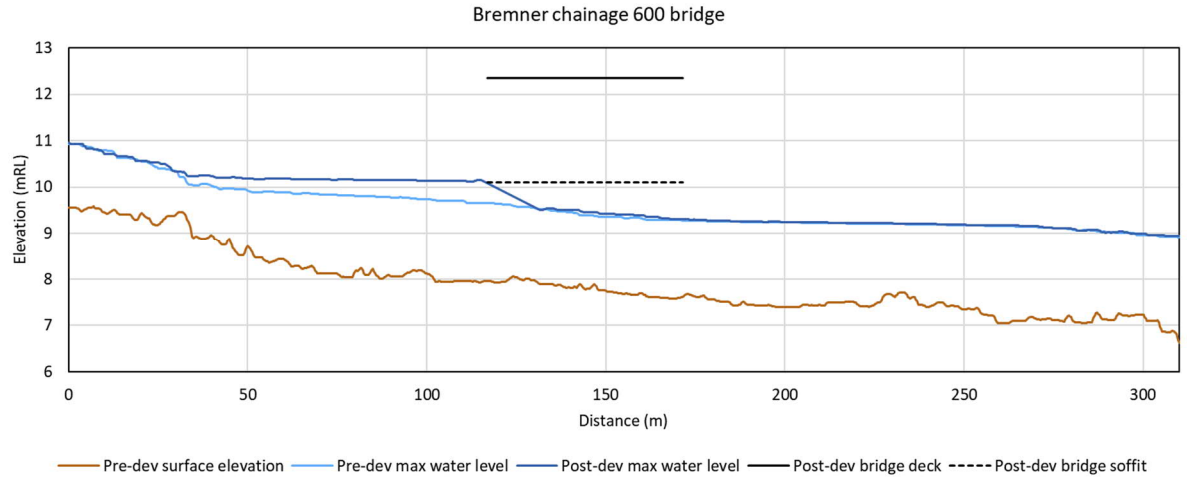


Figure 6-14: Hydraulic grade line (100 year ARI) at Bremner Road and unnamed stream crossing (bridge at chainage 600)

6.3.2.4.2 Bremner / Ngakoroa Stream Bridge

The existing bridge soffit level over Ngakoroa Stream is at RL 3.4m and the existing 100 year flood level upstream of the bridge is RL 6.27 m (with an existing head loss of 160mm). There is currently no freeboard and the bridge will overtop during an extreme rainfall event. The upgraded transport corridor results in a higher vertical alignment over the Ngakoroa Stream but the ability to raise the bridge is limited by overhead high voltage Transpower lines. A raised bridge structure will therefore continue to obstruct the flood flow.

Waka Kotahi is preparing a new two lane bridge design for the Ngakoroa Stream for the Papakura to Drury South State Highway 1 widening project and Bremner Road as it passes over SH1. This is proposed to be constructed in the next few years prior to the NoR D2 works. Waka Kotahi have provided a vertical alignment for the bridge which also passes under Transpower lines (which are located directly over the Bremner Road Bridge) with suitable clearance. This vertical alignment has a sag point of 5.20m on the western approach. NoR D2 proposes to widen the bridge or create an additional two lane bridge to the south for the additional two lanes required in the future.

The widened crossing has been modelled as a 40m bridge with two spans (10m and 30m spans). The upstream flood level is 6.11m with a head loss through the stream crossing is 30mm (the head loss is relatively small as a result of a relatively slow flow velocity). The tailwater level for the post development case will decrease from RL 6.11 to 6.08 due to the concurrent removal of the constriction at the Norrie Road Bridge. With a flood level of RL 6.11, the western approach to the bridge would have negative freeboard and overtop in the 100 year event and the bridge itself will be an obstruction to flood flows (the bridge beams will be submerged by approximately 0.9 to 2m). This arrangement needs to be confirmed with the Papakura to Drury South team once their design has been further progressed.

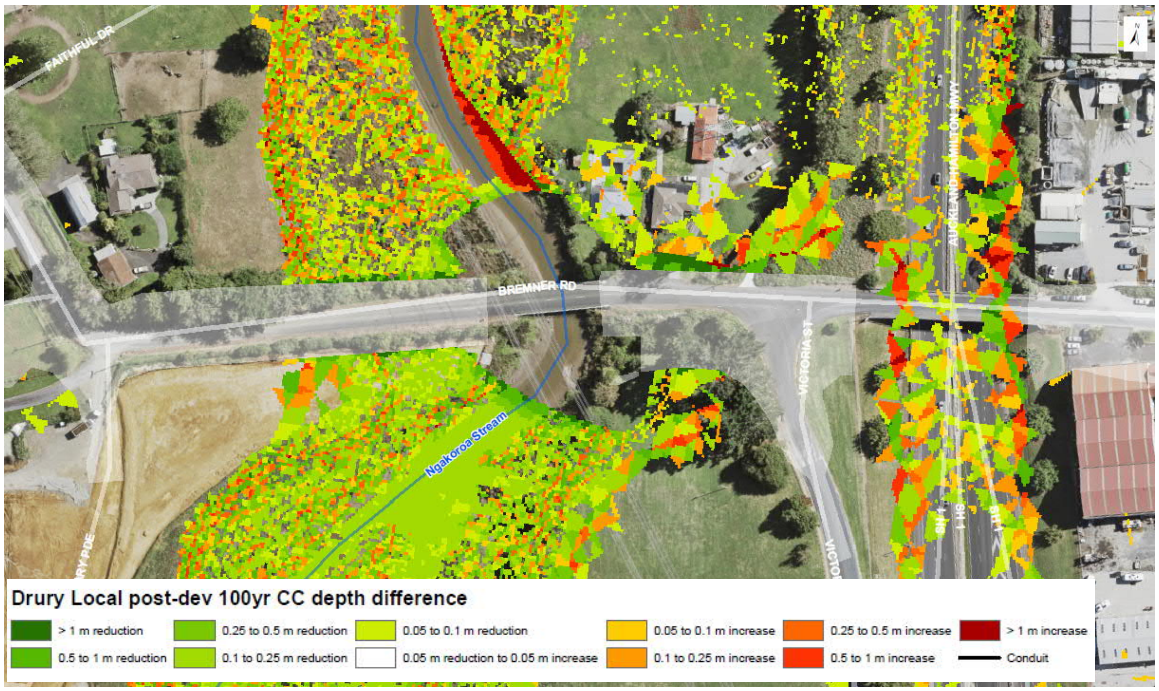


Figure 6-15: 100 Year difference map for post- minus pre-project development at Bremner Road and Ngakoroa Stream crossing

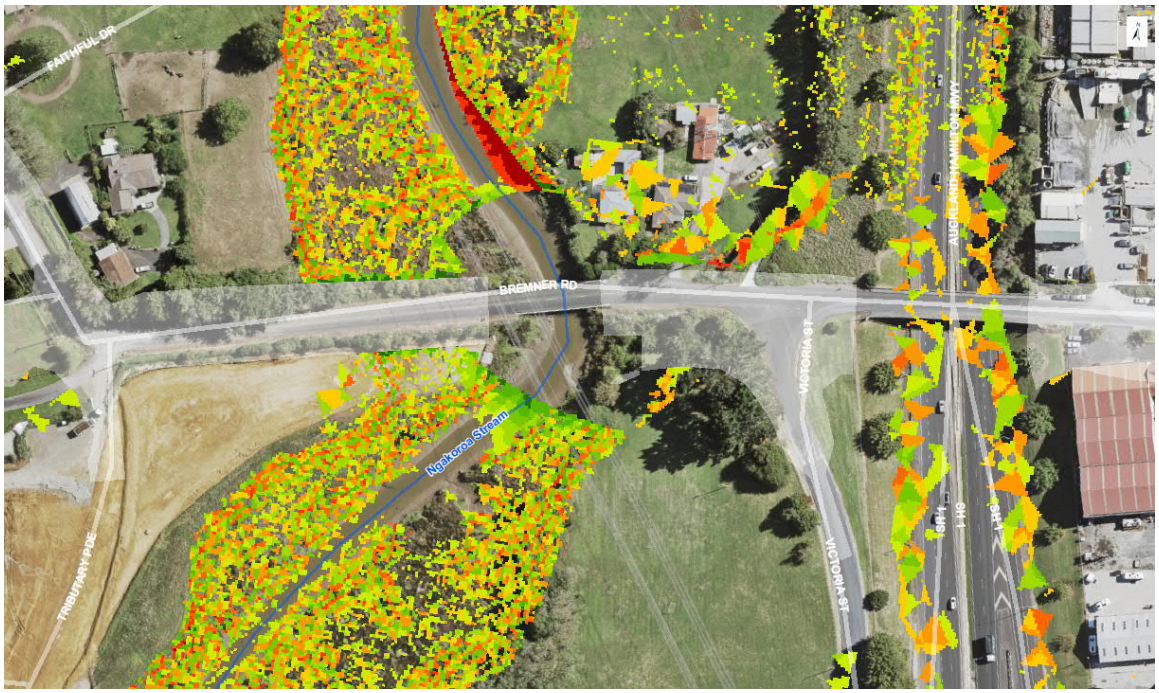


Figure 6-16: 10 Year difference map for post- minus pre-project development at Bremner Road and Ngakoroa Stream crossing

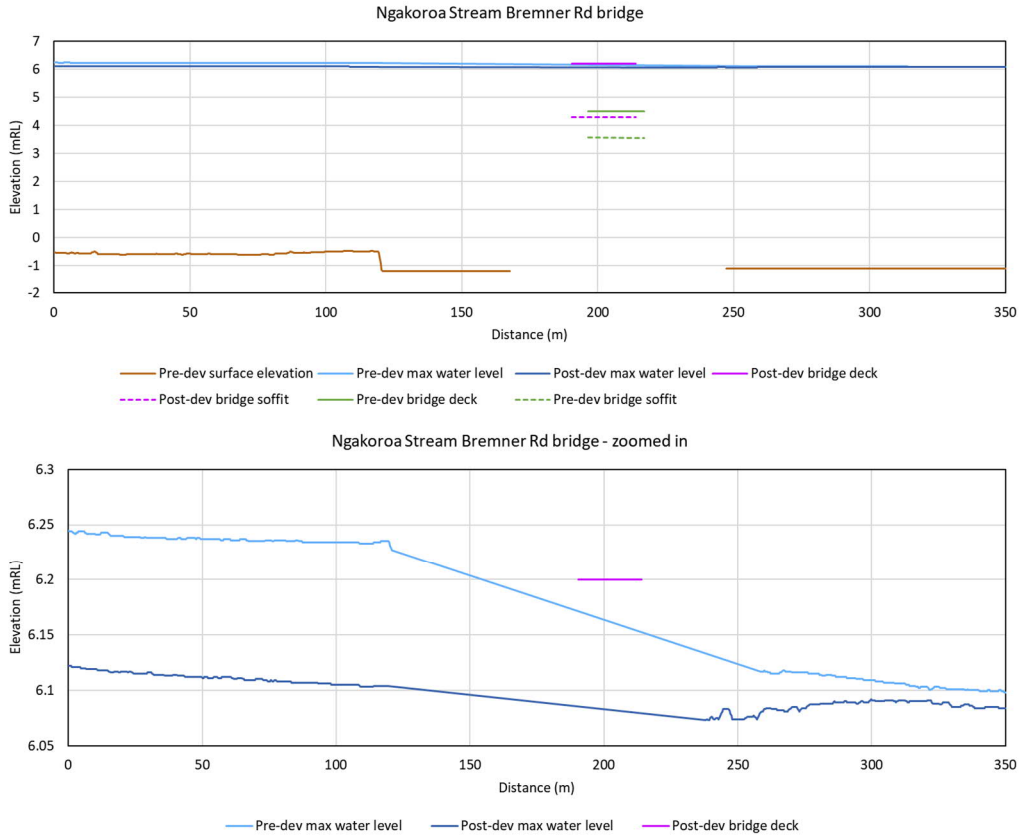


Figure 6-17: Hydraulic grade line (100 year ARI) at Bremner Road and Ngakoroa Stream crossing

6.3.2.4.3 Bremner / Hingaia Stream Bridge

The proposed Hingaia Stream Bridge crossing lies within the Hingaia catchment just downstream of the existing Norrie Road Bridge. The results for the 100 year ARI pre-project development scenario show that the water level upstream of the existing Norrie Road Bridge is RL 8.20 m and RL 7.74 m downstream with flooding extending over the industrial properties and nearby streets with depths ranging between 0.5 m and > 2 m. The Norrie Road Bridge top deck level is RL 6.18 m, overtops by ±2 m and also forms a significant obstruction to flood flows. The existing bridge also overtops in the 10 year rainfall event, with the upstream flood level at RL 6.46 m and the downstream at RL 6.04 m.

The Norrie Road Bridge will be removed, and a new bridge constructed over the Hingaia Stream with a two-span, 70 m long structure and bridge piers outside the main river channel. The results for the 100 year ARI post-project development scenario indicate that the water level reduces to RL 7.79 m (-0.41 m) upstream and RL 7.72 m (-0.02 m) downstream. For the 10 year ARI rainfall event, the upstream water level is RL 6.25 (-0.09m) and the downstream is RL 6.15 (no change). The depth difference map in Figure 6-18 shows the range of reduction in water depths. The decrease in water levels are due to the new bridge having a wider opening of 70 m and a freeboard of 1.0 m between the bridge soffit and 100 year ARI flood level. Further details on the flood levels of Points C through F are shown on Table 6-10 below.

The Hingaia Stream Bridge provides a significant improvement on the existing scenario by improving upstream flood levels and resilience. In general, the 100 year event is reduced by some 0.25 to 0.3m

upstream of the crossing up to Great South Rd. At Great South Road, the depth of flooding overtopping the road reduces by about 0.13 m. In the 10 year event, the depth of flooding is 30 mm lower than the existing case.

The land adjacent to the crossing is zoned Business – Light Industry Zone. The decrease in the height of flooding in this area benefits existing properties and provides a safer environment for the public and business owners by reducing the level and hence the consequences of extreme floods.

The Firth St/Bremner Road intersection is flooded in both the pre-development and post development scenarios. The duration of the flooding for the post development is approximately 3 hours in the 10 year ARI event and 9 hours in the 100 year event. Mitigation such as a temporary road closure may be required. Refer to Table 6-9 below for further details on the flood levels for Points W through to Z regarding the effects on the nearby road and rail crossings shown in Figure 6-18.

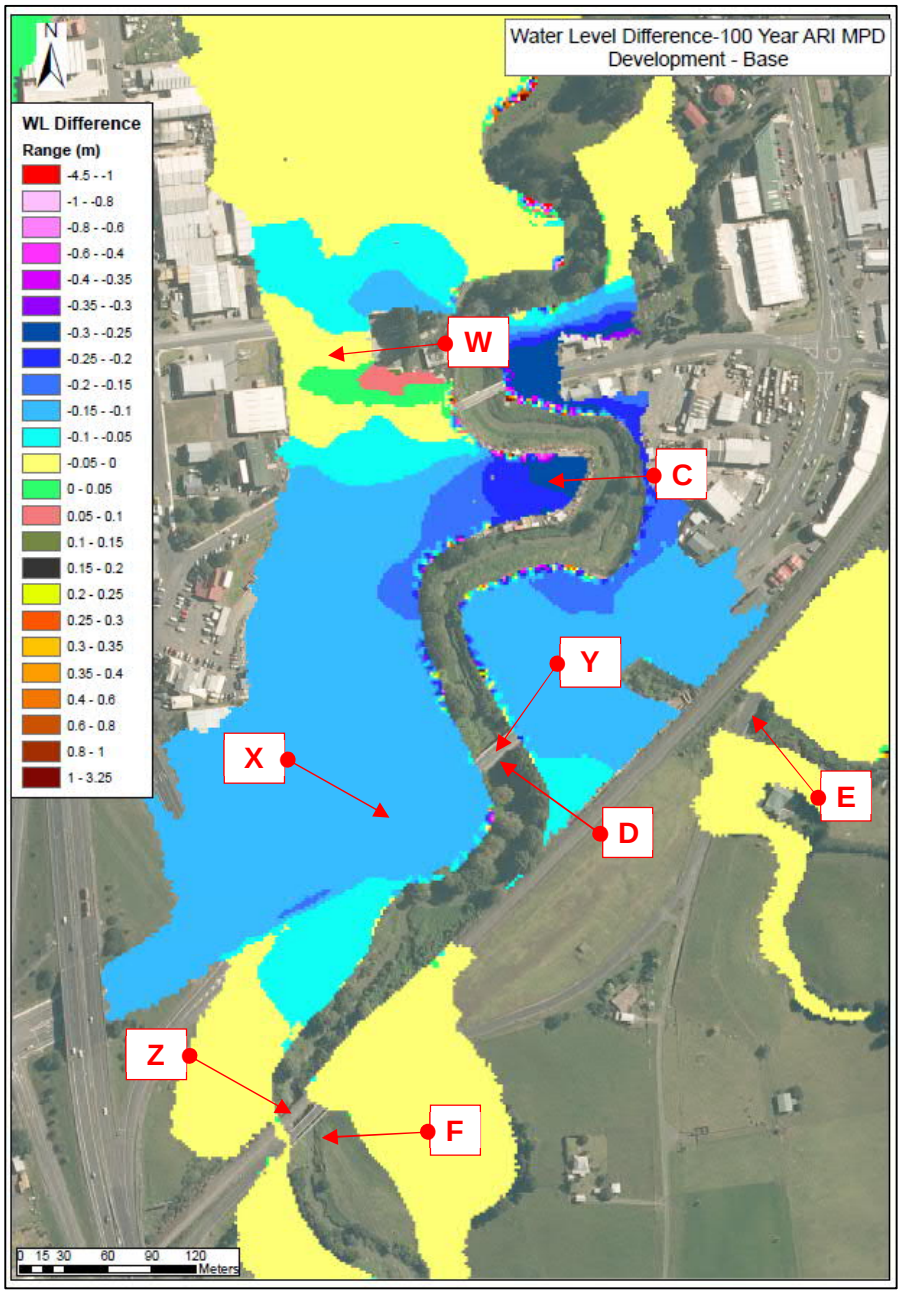


Figure 6-18: 100 Year flood difference map for post- minus pre-project development at Bremner Road and Hingaia Stream crossing

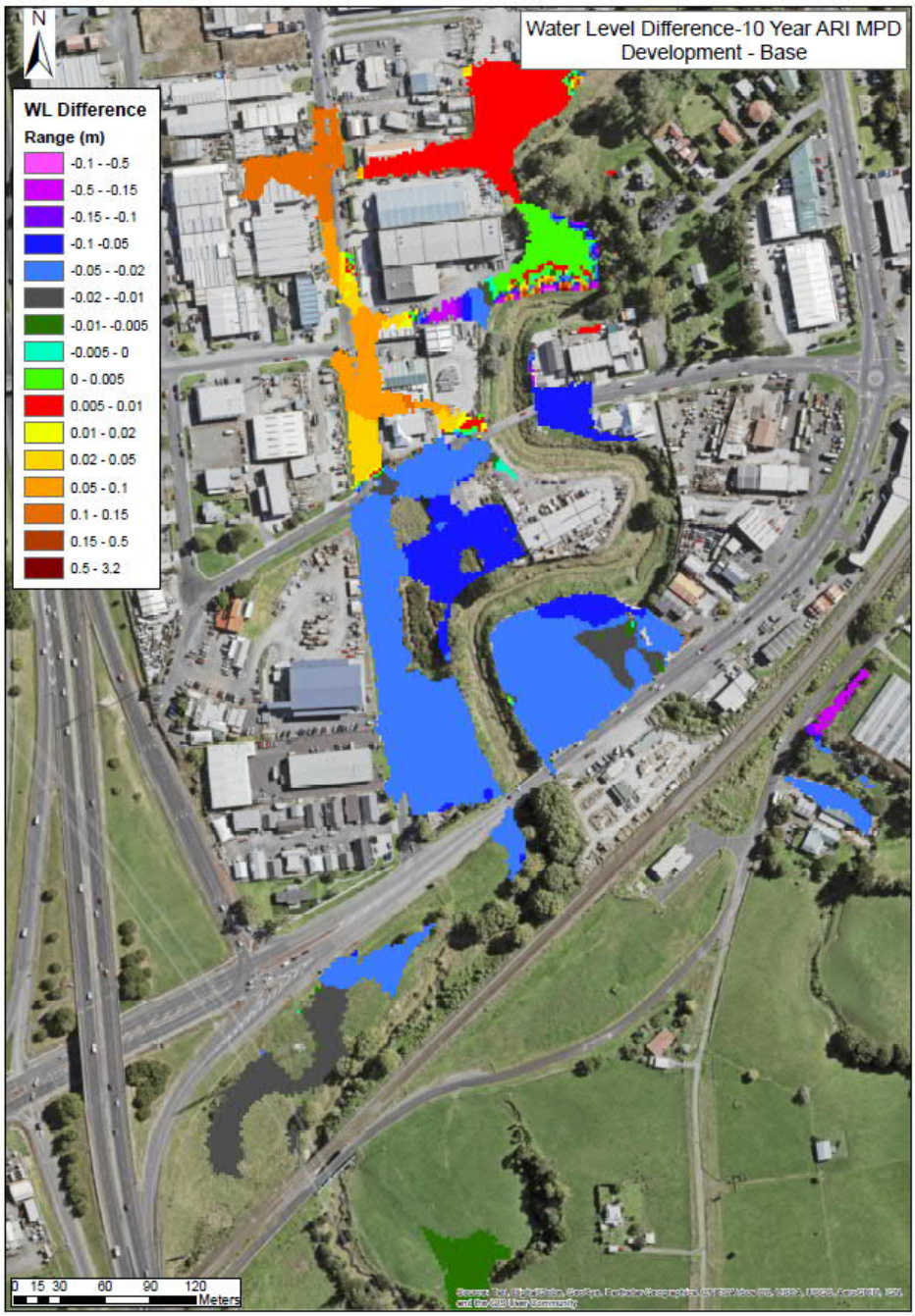


Figure 6-19: 10 Year flood difference map for post- minus pre-project development at Bremner Road and Hingaia Stream crossing

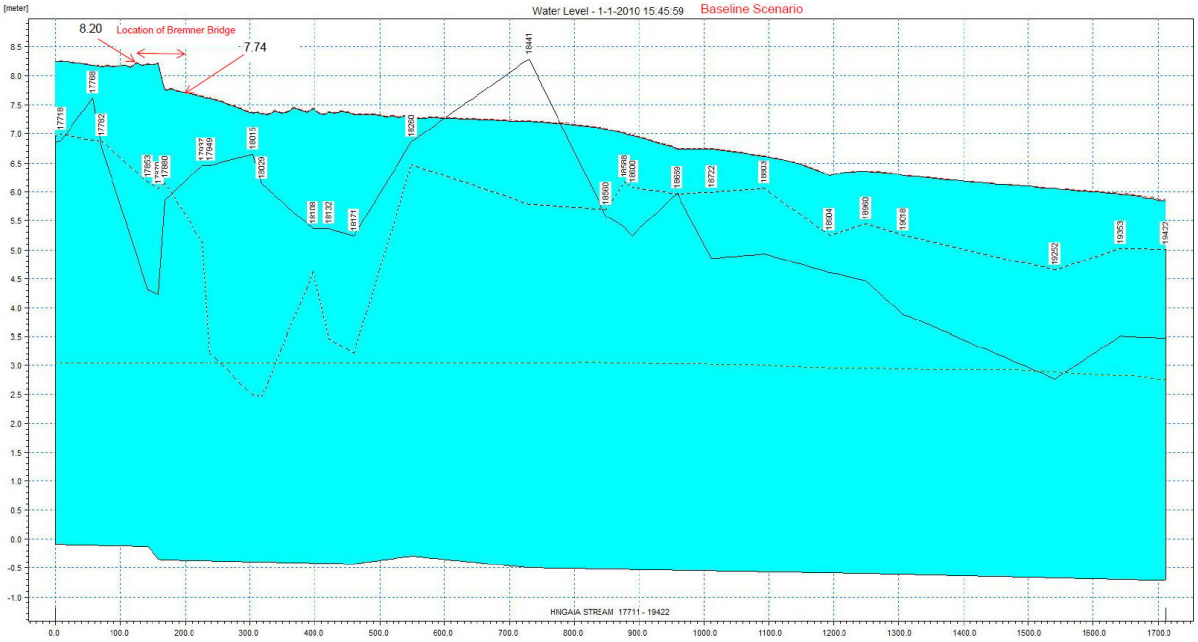


Figure 6-20: Hydraulic grade line (100 ARI) at Bremner Road and Hingaia Stream crossing pre-development

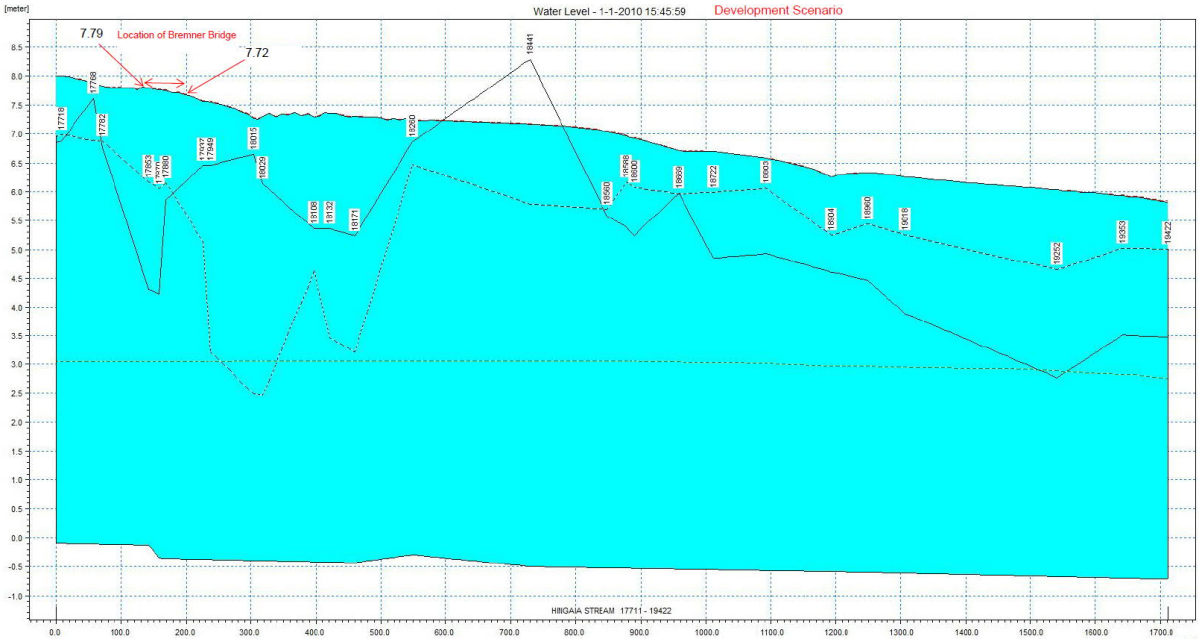


Figure 6-21: Hydraulic grade line (100 ARI) at Bremner Road and Hingaia Stream crossing post-development

Table 6-9: Road and Rail crossings potentially at risk of flooding

Point on the depth difference map	Road / Rail Crossing	Water level difference for 100 year post minus pre-project development	100 Year flood level (RL)	Comments
Point W	Firth St / Bremner intersection	-0.04m	Pre-dev: 7.64m Post-dev:7.60m	Decrease in flood level; positive effect
Point X	Firth St / Great South Road intersection	-0.12m	Pre-dev: 8.48m Post-dev: 8.36m	Decrease in flood level; positive effect
Point Y	Great South Rd bridge over Hingaia Stream	-0.13m	Pre-dev: 8.44m Post-dev: 8.31m	Decrease in flood level; positive effect
Point Z	Kiwirail bridge over Hingaia Stream	-0.03m	Pre-dev: 9.65m Post-dev: 9.62m	Decrease in flood level; positive effect

6.3.2.4.4 Property Assessment

According to the Auckland Council Modelling Specification a freeboard of 500 mm should be added on top of the 100 year ARI MPD flood level for habitable floor levels to have adequate freeboard and safe for use. Buildings floors potentially affected by flood hazards are counted either as being below the 100 year flood level or within 500 mm of the 100 year flood level. Driveways and parking areas should be kept safe from flooding with allowable water depths below 150 mm for cars and 300 mm for trucks.

The difference maps above present the post- minus the pre-project development water levels for the 100 year ARI rainfall event. With reference to Figure 6-12 and Figure 6-18 the properties where flooding levels have changed due to the potential changes to the road's vertical alignment are listed in Table 6-10. These changes in flood levels are considered potential effects, and there are a number of ways that they can be mitigated.

Table 6-10: Properties potentially at risk of flooding along Bremner Road FTN Upgrade

Point on the depth difference map	Property address	Affected area	Water level difference for 100 year post minus pre-project development	100 Year flood level (RL)	Comments
Point A (Fig 6-12)	38 Burberry Road, Drury	Rural land, no habitable floors. FUZ			With refinement of bridge geometry and upstream diversion, negligible effects

Point on the depth difference map	Property address	Affected area	Water level difference for 100 year post minus pre-project development	100 Year flood level (RL)	Comments
Point B (Fig 6-12)	38 Burberry Road, Drury	Rural land, house sited at RL11.5 to 12.0m. FUZ	-0.02m	Pre-dev: 11.11m Post-dev: 11.09m	Decrease in flood level; positive effect
Point C (Fig 6-18)	16 Norrie Road, Drury	Industrial buildings sited at RL 6.5 to 7.0	-0.24m	Pre-dev:8.10m Post-dev: 7.86m	Decrease in flood level; positive effect
Point D (Fig 6-18)	Upstream of Great South Road Bridge	Undeveloped land, and industrial properties at gl RL 7.0 to 8.0m.	-0.09m	Pre-dev:8.60m Post-dev: 8.51m	Decrease in flood level; positive effect
Point E (Fig 6-18)	54 Flanagan Road, Drury	Industrial, commercial buildings. Future rail station.	-0.01m	Pre-dev:8.84m Post-dev: 8.83m	Small decrease in flood level; positive effect
Point F (Fig 6-18)	108 Flanagan Road, Drury	Open space both sides of Hingaia stream	-0.02m	Pre-dev:10.02m Post-dev: 10.0m	Small decrease in flood level; positive effect

6.3.2.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

6.3.2.5.1 Crossing at chainage 600

The proposed road crossing at chainage 600 has the potential to cause increased flood levels upstream if flow is constricted. It is recommended that this crossing be a bridge so that the potential increase in upstream flood levels is minimised, the extent of new flooding minimised and a much larger cross sectional flow area is available to eliminate the risk of culvert blockage forming a flood hazard on FUZ zoned land. The increase in water levels either side of the bridge crossing can be mitigated by a diversion drain along the corridor that conveys water to the main stream. With these works it is expected that the effects on flood levels upstream would be negligible.

6.3.2.5.2 Bremner Road / Ngakoroa Stream Bridge

A new 40m span bridge set at the vertical alignment provided by Waka Kotahi has been modelled. Due to its vertical alignment being controlled by overhead transmission lines, it will form an obstruction to flood flows and gives a 100 year ARI flood level upstream of the bridge of RL 6.11m. this is, however a decrease from the existing flood level, which combined with the higher bridge levels

provides a higher level of safety to road users. No specific mitigation for flood hazard effects are recommended as the head loss and water flow velocity through the bridge is relatively low.

6.3.2.5.3 Norrie Road / Hingaia Stream Bridge

The proposed bridge provides a significantly better flood hazard outcome than the existing bridge with reduced upstream flood levels and the provision of freeboard in both the 100 year and 10 year ARI rainfall events.

A key aspect of this is the removal of the existing bridge which is overtopped by flood flows and causes an obstruction to flood flow. The removal of the existing Norrie Road Bridge should be captured by way of a condition on the designation, which requires the existing bridge be removed during the construction phase of the new bridge.

The Firth St / Bremner Road intersection continues to flood in the 10 year and 100 year post project scenario. Mitigation such as temporary road closures may need to be considered.

6.3.2.6 Summary and Conclusions

Potential construction phase flooding effects can be managed with the proposed mitigation measures set out above. With the proposed Construction Environmental Management Plan taking account of flooding and including measures to address potential flooding, the effects are expected to be minor. Flood hazards for the construction phase should be addressed in the proposed Construction Management Plan. Key issues for the CEMP to consider are:

- siting construction yards and stockpiles outside the flood plain
- minimising the physical obstruction to flood flows under the existing bridge from temporary works
- staging and programming to carry out work when there is less risk of high flow events, and
- methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

Overall, the effect of the Bremner Road FTN Upgrade section will have a positive effect on flooding during the operational phase. This positive effect is the result of a combination of factors including:

- A new bridge at chainage 600m having a negligible effect on flood levels upstream
- A reduction in flood levels and improved freeboard for flood flows to the proposed Ngakoroa and Hingaia Stream Bridges
- Removal of the existing Norrie Road Bridge which currently obstructs flood flows

6.3.3 Waihoehoe Road West FTN Upgrade section

The report assesses the impact from construction and operation due to the flood extents and changes in water levels caused by the upgraded transport corridor. The Waihoehoe Road West FTN Upgrade lies on a ridge and does not have any significant cross-drainage structures. The transport corridor does not encroach on existing flood plains while the existing overland flow paths are further away from the road and are not affected by the upgrade.

6.3.3.1 Assessment of Construction Effects

A tributary of Hingaia Stream runs 200 m to the south of Waihoehoe Road and a tributary of Waihoehoe Stream 700 m to the north of the road. No major construction effects on these existing streams and overland flow paths are expected as Waihoehoe Road West section is located on a ridge, with no culvert or bridge crossings for either of these streams, tributaries or their associated overland flow paths.

A construction yard and stockpile site are proposed at the corner of Great South Road and Waihoehoe Road roundabout which is outside flood plains and major overland flow paths. It therefore does not present any increased flood hazard risks.

Overall, no significant risks associated with flooding during the construction phase have been identified.

6.3.3.2 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

There are no flood hazard issues associated with the proposed construction works of the Waihoehoe Road West FTN Upgrade. Standard earthworks phase controls for diverting overland flow paths around working areas and construction of stormwater infrastructure will be required.

However, flood hazards for the construction phase works should be considered in a proposed CEMP before construction commences once details of construction methods are confirmed. Matters to consider are;

- siting construction yards and stockpiles outside the flood plain
- diverting overland flow paths away from areas of work (in line with standard practice)

6.3.3.3 Assessment of Operational Effects

This assessment of operational effects refers to the flood model results and considers the flooding extents at cross drainage structures, areas where the road embankment encroaches existing flood plains and flooding on existing properties due to the upgraded transport corridor. There are no culvert or bridge crossings over streams on Waihoehoe Road West and therefore will be no effects arising from constrictions or diversion of flow paths. The upgrade of Waihoehoe Road West to a four lane arterial with walking and cycling facilities will increase impervious area and cause some increase in peak runoff from the upgraded transport corridor.

There will be different requirements for flow attenuation depending upon whether flows are discharged to the Hingaia catchment or to the Waihoehoe catchment. It is assumed that flows will be discharged south to the Hingaia catchment and therefore flood flow attenuation is not required (to allow the local peak to be discharged prior to the main catchment peak arriving).

Stormwater discharge locations and any mitigation requirements will be undertaken at the detailed design phase as part of regional resource consents to integrate with the wider area to the south which will be redeveloped for the Drury Central Rail Station (NZUP project) and urban development.

6.3.3.4 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

No specific measures are recommended for flood hazard mitigation during the operational phase.

6.3.3.5 Summary and Conclusions

There are no significant flood hazard issues associated with the construction or operational phase of the Waihoehoe Road West FTN Upgrade. Flood hazards should be considered for the works in a CEMP.

No specific measures are recommended for flood hazard mitigation during the operational phase.

6.4 Conclusions

6.4.1 Jesmond Road FTN Upgrade section

Potential flooding effects arising during the construction phase are able to be managed. With the proposed CEMP taking account of flooding, the effects are expected to be minor.

Overall, the Jesmond Road FTN Upgrade could have some effect on operational phase flood levels at the sag points where overland flow crosses the road transport corridor. With careful design of road levels and upsizing of culverts, flood levels can be managed to be no worse than they currently are and overland flow passed under the corridor. Construction of a formal overland flow path at 119, 125 and 131 Jesmond Road will direct overland flow away from the buildings on site, lower flood levels and could improve the existing situation. Specific matters recommended for conditions on the proposed designation are set out in section 6.4.4.

6.4.2 Bremner Road FTN Upgrade section

Potential flooding effects arising during the construction phase are able to be managed through the proposed Construction Management Plan. At Ngakoroa and Hingaia Streams there may be some increase to flood hazard risks during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridges. However, it is expected that the works can be carried out in a way that will appropriately manage these risks.

A new bridge at Ngakoroa Stream cannot be raised above the flood plain because of the Transpower national grid pylons overhead and, with a 40m span, causes a 160 mm decrease in the 100 year flood level upstream.

The proposed bridge over the Hingaia Stream and removal of the existing Norrie Road Bridge has a positive effect on operational phase flood effects (up to a 340mm decrease) due to the greater conveyance capacity and higher vertical alignment.

Both the Ngakoroa and Hingaia Stream bridges have improved freeboard - with benefits to the safe passage of flow, and safety of those using the bridges and reduced flood levels upstream - with improved safety for the public and properties.

If a culvert is used, there is a potential increase in flood levels greater than 0.5m and creation of a flood prone area affecting future residential development upstream of the proposed transport corridor at chainage 600 on Bremner Road. In addition, as the upstream catchment is 115 ha (generating large flows) and a culvert alternative would be long and large (with consequent ecological effects), a bridge is proposed. A stream diversion is required on the upstream side to keep the bridge length to a single span. With a bridge used, the effect on flood levels upstream will be less than minor and the risk of blockage mitigated.

Specific matters recommended for conditions on the proposed designation are set out in section 6.4.4.

6.4.3 Waihoehoe Road West FTN Upgrade section

There are negligible flood hazard issues associated with the construction or operational phase of the Waihoehoe Road West FTN Upgrade. Any potential flood hazard risks can be addressed in the proposed Construction Management Plan.

No specific measures are recommended for flood hazard mitigation during the operational phase. However, coordination is required to connect the proposed drainage system to the proposed stormwater network in the Drury Central Rail station area.

6.4.4 Recommendations for NoR D2 conditions

Construction effects

It is recommended that a CEMP be developed prior to construction. The CEMP will consider and mitigate potential adverse flood hazard effects. The flood hazard effects shall be assessed by an experienced Stormwater Engineer and shall consider the effects of temporary works, earthworks, storage of materials and temporary diversion and drainage on flow paths, flow depth and velocity.

Operational effects

It is recommended that detailed design should demonstrate:

(i) That the unnamed tributary of the Ngakoroa Stream located at NZTM 1772040, 5891626 is crossed by a bridge

(ii) That the existing Norrie Road Bridge crossing the Hingaia Stream located at NZTM 1773201, 5891836 is removed before the new bridge crossing the Hingaia Stream is opened to the public

It is recommended that during detailed design, that flood modelling of the pre project and post project 100 year ARI flood levels (both for MPD land use and including climate change) is carried out and measures implemented to achieve the following outcomes:

1. 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)
2. 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)
3. 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
4. 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)
5. that there is no more than a 10% average increase of flood hazard (defined as flow depth times velocity) for main access to authorised habitable dwellings.

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

7 NoR D3: Waihoehoe Road East Upgrade

Chapter Summary

The Waihoehoe Road East Upgrade consists of the widening the existing road to a two-lane arterial standard from west of the proposed intersection with Ōpāheke N-S FTN Arterial, to Drury Hills Road in the east. It will tie into the future Mill Road transport corridor NZUP project.

The transport corridor is delineated into four sub-catchments that drain and treat surface runoff. Stormwater management within the corridor will provide stormwater quality treatment and retention/detention for stream health. Stormwater discharge locations will be decided at detailed design to integrate with adjacent future urban development.

The existing land use along Waihoehoe Road East section lies is rural but is zoned Future Urban. Developer interest and the Drury Ōpāheke Structure Plan indicates the likely future environment will consist of Terrace Housing and Apartment Buildings, Mixed Housing Urban and Mixed Housing Suburban.

As the road is located on a ridge there is no significant flooding in the area, with several overland flow paths draining away from the transport corridor in both directions.

There are no significant flood hazard issues associated with the construction or operational phase of the Waihoehoe Road East Upgrade.

There may be some temporary construction phase flooding risk associated with temporary works required for the construction of culverts and stormwater management infrastructure.

However, the details of the construction approach will be confirmed at detailed design. It is expected that the works can be carried out in a way that will appropriately manage the risk, and this can be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

Stormwater management infrastructure is proposed to discharge to existing overland flow paths or be connected to future drainage systems developed as part of future land development. Coordination with affected properties will be required to confirm these connections.

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes and conditions outlined in this report. There is land available within the proposed designation for the stormwater management infrastructure required to manage these potential effects.

7.1 Project Description

7.1.1 Project Overview

The Waihoehoe Road East Upgrade (NoR D3) consists of the widening of Waihoehoe Road to a two-lane arterial with walking and cycling facilities from the proposed intersection with Ōpāheke North-South Arterial, to Drury Hills Road in the east. The functional intent of the Project is to provide strategic east-west connectivity between the strategic north-south corridors (Great South Road, the Ōpāheke N-S FTN Upgrade (NoR D4) and Mill Road), providing multi-modal access to the wider network for the planned growth area as well as providing access to the existing Drury township and proposed rail station (an NZUP project).

The eastern extent of the Project will tie into the future Mill Road corridor which forms a separate NZUP project. The intersection with Ōpāheke North-South is proposed to be signalised, but this work forms part of NoR D2. Roundabouts are proposed at the intersections with Appleby Road and Cossey Road. The road will be an urban arterial with a likely reduced speed limit of 50kph. An overview of the proposed design is provided in Figure 7-1.

Figure 7-1: Overview of Waihoehoe Road East Upgrade

The indicative alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment will be refined and confirmed at the detailed design stage. Key features of the proposed upgrade include the following:

- Widening of Waihoehoe Road from its current general width of 20m to enable a 24m wide two-lane cross-section including separated walking and cycling facilities

- Localised widening around the existing intersections to accommodate the two proposed roundabouts
- Batter slopes to enable widening of the corridor, and associated cut and fill activities.
- Vegetation removal along the existing road corridor
- Areas identified for construction related activities including site compounds, construction laydown, the re-grading of driveways and construction traffic manoeuvring.

7.1.2 Project Features

Stormwater catchments and features are shown on the layout plan for NoR D3 in Appendix 1.

Four catchments are created along the transport corridor. Runoff from catchment 1 drains west and combines with the Waihoehoe Road West (a section of NoR D2) and drains to the Hingaia Stream. Catchments 2, 3 and 4 are treated within the corridor and discharge into overland flow paths leading to the Hingaia Stream.

The proposed transport corridor is designed to follow the existing ground level as far as possible with longitudinal slopes ranging between 0.5% and 4%.

The discharges to the Hingaia Stream lie within the lower third of the stormwater catchment (with flows to be discharged prior to the main catchment peak arriving downstream) and do not require any flood flow attenuation. Stormwater management such as swales or raingardens within the corridor is proposed for water quality treatment. The total catchment size summarized in Table 7-1 includes both the impervious and pervious areas for that catchment.

Stormwater discharge locations from the proposed treatment devices will be decided at detailed design. Integration with future development plans with adjoining properties is required to coordinate the location of outfalls and construction.

Table 7-1: Waihoehoe Road East Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management	Potential Discharge point location (TBC at detailed design)
1	Chainage 800-960 (low point at chainage 800 draining to outlet at chainage 240 Waihoehoe Road West)	4 377 m²	No attenuation required. Storm water quality treatment within the corridor	Overland flow path at 35 Waihoehoe Road, Drury
2	Chainage 960-1400 (low point at chainage 1140)	10 668 m²	No attenuation required. Storm water quality treatment within the corridor	Hingaia Stream tributary

Road Catchment	Catchment Chainages	Total Catchment size	SW Management	Potential Discharge point location (TBC at detailed design)
3	Chainage 1400-2040 (low point at chainage 1660)	18 040 m²	No attenuation required. Storm water quality treatment within the corridor	Hingaia Stream tributary
4	Chainage 2040-2260 (low point at chainage 2000)	9 110 m²	No attenuation required. Storm water quality treatment within the corridor	Hingaia Stream tributary

7.2 Existing and Likely Future Environment

NoR D3 lies within a rural area and is zoned for Future Urban land uses. Developer interest and the Auckland Council Drury-Ōpāheke Structure plan indicate the likely future environment will consist of Terrace Housing and Apartment Buildings, Mixed Housing Urban and Mixed Housing Suburban. A number of plan changes to urbanise the land and developments are proposed in the general area.

The transport corridor lies on a ridge with several overland flow paths draining either north or south, away from the road. A tributary of the Hingaia Stream runs parallel and south of NoR D3 about 200 m to the south. A tributary of the Waihoehoe Stream runs parallel to the road some 50 m to 300 m to the north. The upgraded intersection at Appleby Road crosses an existing overland flow path on the northern side of the intersection.

The Waihoehoe Road East Upgrade lies on a ridge and does not have any cross-drainage structures on the main transport corridor.

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

The report assesses the impact from construction and operation of the corridor on flood extents and changes in water levels.

7.3.1 Assessment of Construction Effects

No major construction effects on streams and overland flow paths are expected.

A construction yard and stockpile site are proposed at the north west corner of Waihoehoe Road and Appleby Road intersection which is outside flood plains and major overland flow paths. It therefore does not present increased flood hazard risks.

Overall, flooding is not considered to be an issue during the construction phase.

7.3.2 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Management of the minor overland flow paths within the corridor will be required to make sure flows are not diverted away from their current flow paths toward existing buildings or property.

The new culvert crossing required for Appleby Road can be constructed offline, offset from the existing culvert crossing which will allow existing flows to be safely managed during construction of the new culvert.

Standard management methods for pipe construction, such as carrying out works during the summer earthworks season and diverting flows if required, will be appropriate to manage risks associated with flooding.

The working area around the drainage system will be dependent on its size, location and volume of water to be managed/diverted. Where no diversion is required and works are carried out offline, ±6 m working clearance will be required to accommodate access and materials. On larger diameter pipes within an overland flow path and requiring diversion, ±20 m beyond the permanent upstream extents and ±15 m beyond the downstream extents should be allowed for.

Flood hazards should be considered for the works in the proposed CEMP. It is recommended a condition be included in the proposed designation to require flood hazards to be assessed through the CEMP.

7.3.3 Assessment of Operational Effects

Flooding associated with the Project works will be less than minor. It is recommended that the flood hazard effects are checked at the detailed design stage for the actual corridor geometry.

7.4 Conclusions

Flood hazard issues associated with the construction and operational phases of NoR D3 will be less than minor. Flood hazards for the construction works should be considered in the proposed Construction Management Plan. Standard conditions for managing potential flooding effects during the construction and operational phases are recommend below.

7.4.1 Recommendations for NoR D3 conditions

Construction effects

It is recommended that a CEMP be developed prior to construction. The CEMP will consider and mitigate potential adverse flood hazard effects. The flood hazard effects shall be assessed by an experienced Stormwater Engineer and shall consider the effects of temporary works, earthworks, storage of materials and temporary diversion and drainage on flow paths, flow depth and velocity.

Operational effects

It is recommended that during detailed design, that flood modelling of the pre project and post project 100 year ARI flood levels (both for MPD land use and including climate change) is carried out and measures implemented to achieve the following outcomes:

1. 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)
2. 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)
3. 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
4. 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)
5. that there is no more than a 10% average increase of flood hazard (defined as flow depth times velocity) for main access to authorised habitable dwellings.

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

8 NoR D4: Ōpāheke North-South FTN Arterial

Chapter Summary

The Ōpāheke N-S FTN Arterial is a proposed new 30 m four-lane FTN arterial across greenfields areas between Hunua Road in the north and Waihoehoe Road in the south.

NoR D4 provides a new north-south connection between Drury and Papakura and involves; new intersections with Hunua Road, Walker Road, Ponga Road and Waihoehoe Road, a new bridge approximately 120m long over the Waipokapu (Hays) Stream, a new approx. 265m bridge over the Mangapū / Waihoehoe Streams (and the associated 690m wide flood plain), a number of culverts and four wetlands.

The transport corridor is delineated into seven sub-catchments. Six of the sub-catchments drain surface runoff towards four proposed wetlands for stormwater management. The four wetlands are sized for stormwater quality treatment, retention/detention for stream health and flood attenuation. The remaining catchment connects to the existing stormwater network at Hunua Road.

The existing land use along the new Ōpāheke N-S FTN Arterial is mostly rural / Future Urban, with Business zoning at Hunua / Boundary Road and Open Space around the main stream corridors (esplanade reserve). The Drury-Ōpāheke Structure Plan shows the likely future land use as a mix of residential land uses along with a smaller amount of industrial and business uses.

Several streams, flood plains and overland flow paths cross the proposed transport corridor. The existing 100 year ARI flood information from Auckland Council's Geomaps show a ± 690 m wide flood plain around Waihoehoe Stream that floods properties at Harry Dodd Road. The concept design has taken these constraints into account.

This assessment considers the potential flood hazard effect of the proposed transport corridor during its construction and operational phases on the flood extents and water levels in the surrounding area.

It is anticipated that the new bridge over the Waipokapū Stream, at 120 m long, will span the stream channel and floodplain. The new bridge over the Waihoehoe Stream will span the main stream channel and part of the adjacent floodplain – but given the large floodplain width it is expected that embankments will be constructed within some 400m of flood plain. Temporary platforms near the stream banks and within the floodplain will be required for bridge construction works. Culverts will either be constructed entirely offline or require temporary diversions and damming. The wetlands near the Waihoehoe Bridge and a construction yard may be located in the downstream "shadow" of the bridge approaches within the flood plain.

There may be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridges and the construction yard. However, the details of the construction approach have yet to be confirmed at this time. It is expected that the works can be carried out in a way that will appropriately manage the risk and this will be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP). Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

The potential operational phase flooding effects have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development terrain) flood model results at new culverts, bridge crossings and existing properties either side of the Waihoehoe Stream viaduct (at Harry Dodd Road and Sutton Road).

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes and conditions outlined in this report.

The majority of land upstream of the corridor is zoned future urban and therefore, depending upon the timing of the construction of the corridor and potential upstream development, there could be operational effects on either the existing dwellings (at Walker Road and Harry Dodd Road) or the potential upstream development.

In terms of existing properties, there are potential increases in flood levels identified for properties at 105 Walker Road and Harry Dodd Road. The flooding at 105 Walker Road can be mitigated by an overland flow path to be constructed within the designation. Within 125m upstream of the proposed Waihoehoe Stream Bridge the flood difference maps show that there is less than 50mm of change, with existing properties at Harry Dodd Road identified as experiencing up to a 30mm increase in flood levels. We consider that the increase of up to 50mm shows that the proposed bridge and approaches over the Waihoehoe Stream can be constructed within an acceptable level of effects. However, it is anticipated that up to five existing dwellings may have freeboard less than 500mm and, if this is confirmed, further optimisation of the bridge arrangement or some local mitigation may be required. It is recommended that the magnitude of the effect is confirmed at the detailed design phase and, for any existing habitable floors experiencing more than a 10% reduction in freeboard, mitigation is provided.

In terms of potential upstream development within the future urban zone, the corridor construction introduces two operational flooding effects; changes in upstream flood levels - thereby affecting the level at which future habitable floor levels are set, and the creation of flood prone land. If development of the Future Urban zoned land within the floodplain is to be realised it is expected that habitable buildings would not be allowed within the current floodplain extents, earthworks within/adjacent the flood plain would be undertaken to form development sites and building floor levels would be constructed above the existing floodplain with appropriate freeboard. Given the degree of earthworks change in the catchment and the modelled minor changes in flood levels, it expected that the predicted changes in flood levels identified can be easily accommodated. The flood prone issue relates to the corridor embankment forming an upstream pond in some areas (chainages 1400, 2500 to 2700 and 3000 to 3700) if the capacity of cross drainage is blocked or overwhelmed. This can be avoided by setting habitable floor levels above the level of the completed road or mitigated by upsizing culverts and providing inlet protection/secondary inlets/overland flow paths (for which there is space within the proposed designation). In both of these operational flooding cases, it is recommended that coordination occur with Auckland Council and adjacent property owners/developers to address these issues through detailed design of the Project and upstream development design processes.

Most of the land identified for future stormwater management wetlands is outside flood plains. Wetlands 3 and 4 are constrained and have had to be placed downstream of the bridge in the edge of floodplains in low water velocity areas. This is considered low risk with further assessment of the risk of scour and overtopping and mitigation recommended for the detailed design phase.

Overall, it is considered that the potential flooding effects arising from the proposed transport corridor for NoR D4 can be adequately mitigated and that there is land available within the proposed designation to provide for the required works.

8.1 Project Description

8.1.1 Project Overview

The Ōpāheke North-South FTN Arterial is a new 30m four-lane FTN arterial with separated walking and cycling facilities between Hunua Road in the north and Waihoehoe Road in the south. The road will be an urban arterial with a likely speed limit of 50kph. The functional intent of the Project from a transport perspective is to increase connectivity and provide for good people-movement and public transport function through the FUZ. The Project will also support SH1, Great South Road and the proposed Mill Road corridor by providing a new corridor which will cater more to local north-south trips in Drury.

The road traverses greenfields zoned FUZ, crossing approximately seven streams (or tributaries of streams) and areas of flood plain, providing a new north-south connection between Drury and Papakura. The intersection with Hunua/Boundary Roads will be signalised, and roundabouts are proposed at Ōpāheke Road / Ponga Road, Walker Road and Waihoehoe Road. The intersection at Waihoehoe Road is not included in this project extent (it is included within NoR D2). An overview of the proposed design is provided in Figure 8-1.

During project consultation, work has been carried out with Oyster Capital Ltd to revise the southern part of the alignment through 116, 136 and 140 Waihoehoe Road . Oyster Capital Ltd have an unconditional agreement to purchase this land and have lodged a plan change request with Auckland Council for the development of the land. The alignment shift was agreed with Oyster Capital Ltd in December 2020 and has been incorporated into this assessment. As the revised alignment was still some distance from habitable floors and is within a low velocity part of the flood plain, it is considered that the alignment change and did not need to be remodelled. Modelling of the final alignment will be undertaken at detailed design as a condition on the designation.

The indicative alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment will be refined and confirmed at the detailed design stage. Key features of the proposal include the following:

- A new road to enable a 30m wide four-lane cross section including bus lanes and separate walking and cycling facilities
- Localised widening around intersections with existing roads to accommodate vehicle stacking and tie-ins and walking and cycling facilities/crossings
- Proposed new culverts

- Four proposed stormwater wetlands
- Two proposed bridges over Waipokapū Stream (approximately 120m long) and Waihoehoe Stream and floodplain (approximately 265m long)
- Batter slopes and retaining to enable construction of the corridor, and associated cut and fill activities
- Vegetation removal
- Areas identified for construction related activities including site compounds, construction laydown, bridge works area, the re-grade of driveways and construction traffic manoeuvring

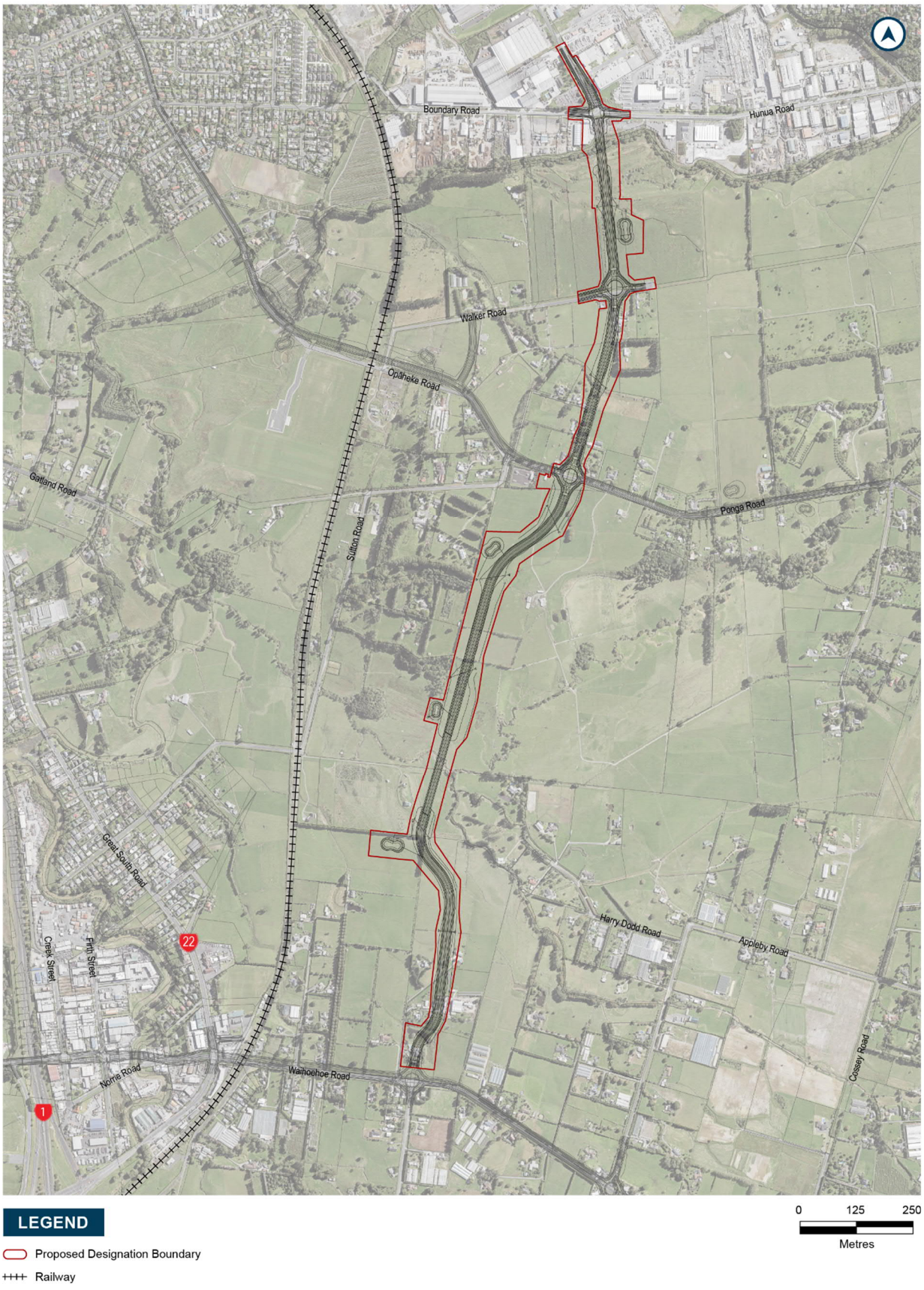


Figure 8-1: Overview of Ōpāheke N-S FTN Arterial

8.1.2 Project Features

Stormwater catchments and features are shown on the layout plan for NoR D4 in Appendix 1.

The transport corridor has seven sub-catchments:

- Catchment 1 drains north west towards the low point on Hunua Road where it is proposed to be managed by devices such as raingardens and swales within the designation with an outlet connected to the existing stormwater network
- Catchment 2 will be collected and discharged into Wetland 1 for treatment and attenuation and will be discharged into the Waipokapū Stream tributary.
- Catchments 3 and 4 will be collected and discharged into Wetland 2 for treatment and attenuation and from there into a Waihoehoe Stream tributary.
- Catchments 4 and 5 will be collected and discharged into Wetland 3 for treatment, retention and flood attenuation and discharge into the main stem of the Waihoehoe Stream.
- Catchments 6 and 7 will be collected into Wetland 4 and discharge into a Waihoehoe Stream tributary.

The proposed transport corridor crosses two major streams, namely Waipokapū Stream and Waihoehoe Stream, their tributaries and overland flow paths. The longitudinal slopes of the transport corridor range between 0.5% and 4% which allows for enough gradient to drain stormwater runoff from the transport corridor via catchpits into an underground pipe system.

The increased surface runoff generated by the additional impervious surface area due to the new transport corridor, will require flood mitigation to attenuate the 100 year ARI rainfall event and discharge at pre-project development flows.

Wetland 3 and 4 have been located on the edge of the Waihoehoe Stream floodplain in the downstream shadow of the bridge embankments. Outside the floodplain on the north side is steeper (leading to more significant earthworks) and has a small stream surrounded by trees. To the south, the floodplain is spread wide and therefore functionally needs to be within the floodplain.

The total catchment sizes summarized in Table 8-1 includes both the impervious and pervious areas for that catchment.

Table 8-1: Ōpāheke N-S FTN Arterial catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management type	Attenuation volume provided	Size of wetland permanent water	Discharge point location
1	chainage 400 - 720 (low point at chainage 400)	15 300 m²	Stormwater treatment and retention/detention with flood mitigation for the 10 and 100 year ARI rainfall events	422 m³	n/a	Existing manhole, ID:2001096089
2	chainage 720 - 1760 (low point at chainage 960m) Also bridge at ch1500	31 200 m²	Wetland 1 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall event	1 426 m³	600 m³	Waipokapū Stream tributary at 158 Walker Road, Drury
3	chainage 1760 - 2300 Also culvert at local low point at chainage 2220	19 100 m²	Wetland 2 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall events	610 m³	375 m³	Waihoehoe Stream tributary at 61 Ponga Road, Drury
4	chainage 2220 - 2520	9 600 m²	Wetland 3 for quality treatment,	512 m³	277 m³	

Road Catchment	Catchment Chainages	Total Catchment size	SW Management type	Attenuation volume provided	Size of wetland permanent water	Discharge point location
	Also culvert at local low point at chainage 2520		retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall events			Waihoehoe Stream at 205 Sutton Road, Drury
5	chainage 2520 - 2680	4 800 m^2				
6	chainage 2680 - 3620 (low point at chainage 3120) Also culverts at local low points at chainage 3040 and 3530	28 200 m^2	Wetland 4 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI events	1 309 m^3	658 m^3	Waihoehoe Stream tributary at 201 Sutton Road, Drury
7	chainage 3620 - 3820m (low point at chainage 3700) Also culvert at local low point at chainage 3680	6 000 m^2				

A potential set of cross drainage structures for this transport corridor including bridges and culvert crossings are used to assess the potential flooding effects and are summarized in Table 8-2. Bridge structures are required over Waipokapū and Waihoehoe Streams, while culvert crossings could be used for a Waipokapū Stream tributary and several overland flow paths. The type and size of cross drainage structures are not fixed and will continue to be assessed through subsequent consenting and design phases.

Table 8-2: Ōpāheke N-S FTN Arterial cross drainage characteristics

Chainage	Upstream catchment (ha)	Modelled Cross drainage	Modelled Bridge Levels (RL) m
chainage 740	1 666	Waipokapū Stream Bridge, four-span, 120m long	Bridge soffit level at 19.76m
chainage 930	55	1800mm dia. culvert	
chainage 1500	39	3.0 x 1.5m box culvert	
chainage 1940	3.2	975mm dia. culvert	
chainage 2220	16	1650mm dia. culvert	
chainage 2520	3.7	900mm dia. culvert	
chainage 2720 - 3000	1 593	Waihoehoe Stream Bridge: Seven 35m spans, 245m long Eight 35.6m spans, 285m long	Bridge soffit level at 10.9m
chainage 3380	3.2	1650mm dia. culvert	
chainage 3680	2.7	1950mm dia. culvert	

8.2 Existing and Likely Future Environment

The existing land use along the new Ōpāheke N-S FTN Arterial is mostly rural with business zoned areas at Hunua / Boundary Road and open space (esplanade reserve).

With reference to the Auckland Council Drury-Ōpāheke Structure plan and the AUPOIP, the land is identified as FUZ and the Structure Plan identifies future zones for Heavy and Light Industry, Terrace Housing and Apartment Buildings and Mixed Housing Urban. Developer interest in the south part of NoR D4 generally aligns with that in the Drury-Ōpāheke Structure Plan. The existing open space has a low likelihood to change in the future. Permanent and intermittent streams with a 20 m riparian margin and flood plains are also identified in the Drury-Ōpāheke Structure plan.

Waipokapū Stream, Waihoehoe Stream and several overland flow paths cross the proposed transport corridor and run into Ōtūwairoa Stream. The transport corridor crosses an existing pond north of Waihoehoe Road that discharges into a tributary of Waihoehoe Stream.

Several overland flow paths and streams cross the proposed new transport corridor, and flood prone areas are evident at some of these crossings. The 100 year ARI flood maps from the Auckland

Council's Geomaps show an 80 m wide flood plain over Waipokapū Stream and a ± 690 m wide flood plain over Waihoehoe Stream.

Earthworks for development within the FUZ upstream of the Ōpāheke N-S corridor will change catchment hydrology, the terrain and building and property types that are potentially exposed to flooding along most of the corridor. Specific issues could include modification of the width and depth of the floodplain around the Waihoehoe Stream and development of low lying land upstream of the corridor around chainage 1500m and 2200m. The assessment has therefore considered specific effects on existing properties and more generally considered effects on potential future development. It is expected that coordination and integration of the corridor design with FUZ development will be required to confirm and address potential future effects.

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

This section of the report assesses the impact from construction and operation of the proposed arterial on flood extents and changes in water levels. A 2D flood model for the Ōtūwairoa Stream (Slippery Creek) catchment has been generated for the pre- and post-project development scenarios for the 10 and 100 year rainfall events. This assessment of effects refers to the model results and considers the flooding extents at culvert crossings, bridge structures and significant areas where the new road embankment encroaches existing flood plains. Table 8-3 summarizes flood levels for the pre-project development and post-project development scenarios.

Table 8-3: Ōpāheke N-S FTN Arterial flood levels at cross drainage

Chainage	Modelled Cross drainage	Pre Project flood level (MPD + CC) (RL)	Modelled post development scenario	Road Design Level at Centre Line (RL)	Post Project flood level (MPD + CC) (RL)
chainage 740	Waipokapū Stream Bridge structure, four-span, 120m long	100 year ARI rainfall event: 18.63m upstream, 18.36m downstream	Bridge soffit level at 19.76m	23.12m	100 year ARI rainfall event: 18.67m upstream, 18.35m downstream
chainage 930	2000mm dia. culvert	100 year ARI rainfall event: 17.71m upstream, 17.71m downstream	14.6m upstream, 14.0m downstream	19.63m	100 year ARI rainfall event: 18.05m upstream, 17.71m downstream
chainage 1500	3.0 x 1.5m box culvert	100 year ARI rainfall event: 18.85m upstream, 18.16m downstream	17.5m upstream, 16.5m downstream	22.84m	100 year ARI rainfall event: 19.56 upstream
chainage 1940	1650mm dia. culvert	100 year ARI rainfall event: 21.0m upstream, 18.23m downstream	20.6m upstream, 18.9m downstream	24.06m	100 year ARI rainfall event: 21.38m upstream, 18.06m downstream
chainage 2220	2000mm dia. culvert	100 year ARI rainfall event: 16.51m upstream, 15.07m downstream	14.8m upstream, 14.3m downstream	20.45m	100 year ARI rainfall event: 16.99m upstream, 14.97m downstream
chainage 2520	1650mm dia. culvert	100 year ARI rainfall event: 17.06m upstream, 9.55m downstream	16.9m upstream, 10.5m downstream	17.62m	100 year ARI rainfall event: 17.50m upstream, 9.41m downstream

Chainage	Modelled Cross drainage	Pre Project flood level (MPD + CC) (RL)	Modelled post development scenario	Road Design Level at Centre Line (RL)	Post Project flood level (MPD + CC) (RL)
chainage 2720	Waihoehoe Stream Bridge structure Options: seven spans, 245m eight spans 285m	100 year ARI rainfall event: 9.72m upstream, 9.28m downstream	Bridge soffit level at 10.9m	14.41m	100 year ARI rainfall event: 9.81m upstream, 9.36m downstream
chainage 3380	1650mm dia. culvert	100 year ARI rainfall event: 12.17m upstream, 11.50m downstream	12.0m upstream, 11.9m downstream	14.22m	100 year ARI rainfall event: 12.82m upstream, 11.37m downstream
chainage 3680	1950mm dia. culvert	100 year ARI rainfall event: 15.84m upstream, 15.77m downstream	15.36m upstream, 15.38m downstream	17.14m	100 year ARI rainfall event: 16.05m upstream, 15.67m downstream

8.3.1 Assessment of Construction Effects

Construction works have the potential to affect overland flow paths, the Waihoehoe Stream and its tributaries and the Waipokapū Stream and its tributaries. At the proposed arterial location, the Waihoehoe Stream and its tributaries make up a wide flood plain (±690 m). This section assesses the potential effects of these construction works, and section 8.3.2 recommends potential mitigation measures to address these effects.

Works include eight new culvert crossings, two new bridges, open channels and four new stormwater wetlands and associated outlets. Of these works, the majority can be constructed off-line from existing flow paths or use diversions to isolate working areas.

There are limited risks associated with flooding during construction as the bridges proposed are of wide spans and there are few nearby buildings that could be affected. The likely higher risks are expected to be:

- Temporary works at Waipokapū Stream creating a constriction to flood flows – potentially affecting industrial land
- Earthworks potentially obstructing overland flows at around chainage 1900
- Obstruction of overland flows for the construction of the culvert at chainage 1500 and 2200
- Obstruction of overland flows for the embankment earthworks and construction of culverts at chainage 3550 and 3680 close to upstream properties
- Materials stored within the flood plain being washed downstream

The new bridge over the Waipokapū Stream has a central span of 30m which is long enough to bridge over the stream bed and avoid effects from siting piers on the stream bed and channel. This avoids the need for diverting flow in the deepest and fastest flowing section of stream, which consequently reduces the risk of erosion and blockage of the main stream flow path, which could lead to flooding during construction. Similarly, at Waihoehoe Stream, the piers for the central span of 35m have been placed and aligned to be sited either side of the stream banks which will also reduce the risk of erosion and blockage of the main flow path of this stream.

The bridges over Waipokapū Stream, and Waihoehoe Stream will require temporary staging platforms for piling rigs and cranes to be constructed near the banks of the main stream channel. These platforms could cause a constriction to flood flows (once flow overtops the stream banks and starts to occupy the flood plain) and cause a backwater effect raising upstream flood levels. Several properties upstream of the proposed Waipokapū Stream and Waihoehoe Stream crossings are sited within or adjacent to the flood plain. Therefore, the combination of a temporary constriction at the bridges and an extreme flood means there is conceptually an elevated risk of flooding to those properties for the duration of the temporary works being in place. The likelihood of this occurring is however low (a 100 year event) and is only slightly greater than the existing situation (it is a very small additional constriction relative to the size of the flood plain).

Various new culverts need to be installed. Flow paths need to be maintained during construction to minimise the risk of creating obstructions and flooding. The new culverts can generally be constructed offline and flow maintained through the existing flow paths during construction to minimise flood risk.

Five construction yards are located along the transport corridor but are outside flood plains and major overland flow paths except for one, which is proposed on the downstream side of the Waihoehoe Stream viaduct crossing. Site compound 4 and sediment retention pond 4 are both located within the flood plain near the Waihoehoe viaduct and therefore might present an increased flood hazard risk. However, they have a functional requirement to be located here to enable the efficient construction of the bridge and surrounding land is generally steeper and not suited to a yard.

8.3.2 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

8.3.2.1 Boundary Road/ Hunua Road intersection works and Bridge

Waipokapū Stream Bridge

This bridge consists of four spans with piers located on the stream banks, including spill-through-abutments, capable of catering for larger stream flows.

To minimise the risk of flooding, temporary works should be set back as far as practicable from the main stream channel and channel work carried out during low flow conditions. Staging of works and stockpiling of materials outside the flood plain will also mitigate the potential for blocking flow paths and flood plains. Works to construct piers should be from platforms outside the stream bed and banks.

8.3.2.2 South of Bridge 1 to Ponga Road/ Ōpāheke Road intersection

Wetlands

The proposed wetland 1 will be located as described above, with a discharge outlet to Waipokapū tributary stream. The outlet can be constructed offline.

Culverts

A culvert crossing is proposed at the Waipokapū stream tributary. A temporary stabilised watercourse diversion will be appropriate to manage flood risk and achieve a dry works area.

8.3.2.3 South of Ponga Road/ Ōpāheke Road intersection to Waihoehoe Road

Waihoehoe Stream Viaduct

The proposed bridge over the Waihoehoe Stream consists of 8-spans and spill through abutments. The bridge spans approximately 265 m across the Waihoehoe Stream and floodplain, immediately downstream of the junction with Mangapū Stream. Methods such as dry season work, staging and diversion of overland flow will be required to minimise the risk of foundations and abutments being inundated during their construction.

The existing flood plain is over 600m wide in both the 100 and 10 year rainfall events. Works cannot therefore be avoided within the flood plain. Inspection of the flow velocity vectors from the flood model shows that the edges of the flood plain are slow flowing. It is recommended that the site compound and sediment retention pond be located near the edge of the flood plain where it is expected that flow will be shallower and slower and there is a reduced risk of materials being moved by flood water.

Given the large scale of earthworks, there is a risk of materials and sediment reducing the capacity of downstream drainage which may lead to flooding issues. This risk should be considered further in the CEMP with respect to sediment controls and storage of materials within the flood plain.

Wetlands

The proposed wetland 4 will be located at chainage ±3100 m as described above, with a discharge outlet 165 m west of the wetland into a tributary of the Waihoehoe Stream. The wetland, outlet and discharge pipe are located within the flood plain described above. Dry season works and flow diversion may be required to keep the area of works dry, which should be addressed as part of the CEMP.

Culverts

Seven new culvert crossings are proposed in this southern area. Overland flow path diversions and stream diversions will be required, particularly for crossings with larger embankments requiring a longer duration of works or for overland flow paths with more regular and higher flow rates. Care is required for works with nearby adjacent properties such as at chainages 1900, 2200 and 3500 at low lying levels relative to the corridor.

Working area around the culverts will be dependent on the culvert size and location and flow rate of water to be managed/diverted. Where no diversion is required and works are carried out offline, ±6 m working clearance will be required to accommodate access and materials. On larger diameter pipes within the overland flow path and requiring diversion, ±20 m beyond the permanent upstream extents and ±15 m beyond the downstream extents should be allowed for.

8.3.2.4 Mitigation

For all areas, flood hazards should be addressed in the CEMP. Key issues to consider are:

- siting construction yards and stockpiles outside the flood plain, or in the case of the Waihoehoe Stream near the edges of the flood plain away from higher flow areas
- minimising the physical obstruction to flood flows at bridges due to temporary works
- diversion of overland flows away from any longer term working areas within the flood plain
- staging and programming to carry out work when there is less risk of high flow events, and
- methods to reduce the conveyance of sediment, or materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

It is recommended that a condition to the NoR require flood hazard to be considered further through the CEMP.

8.3.3 Assessment of Operational Effects

This assessment of effects refers to the existing (pre-project development) and future (post development) flood model results and considers the flooding extents at new culvert crossings (≥ 600 mm dia.), bridge structures and significant areas where the new road embankment encroaches existing flood plains. The assessment also considers the extents of flooding on existing properties due

to the new transport corridor. The following key areas are identified and described in more detail in the sections below:

- Waipokapū Stream Bridge
- Waihoehoe Stream viaduct, culvert at chainage 3050 and properties around Harry Dodd Road
- Culverts at chainage 3500 and chainage 3670

Flood levels are shown as the red points on Figure 8-2 to Figure 8-7 and are summarised in Table 8-4.

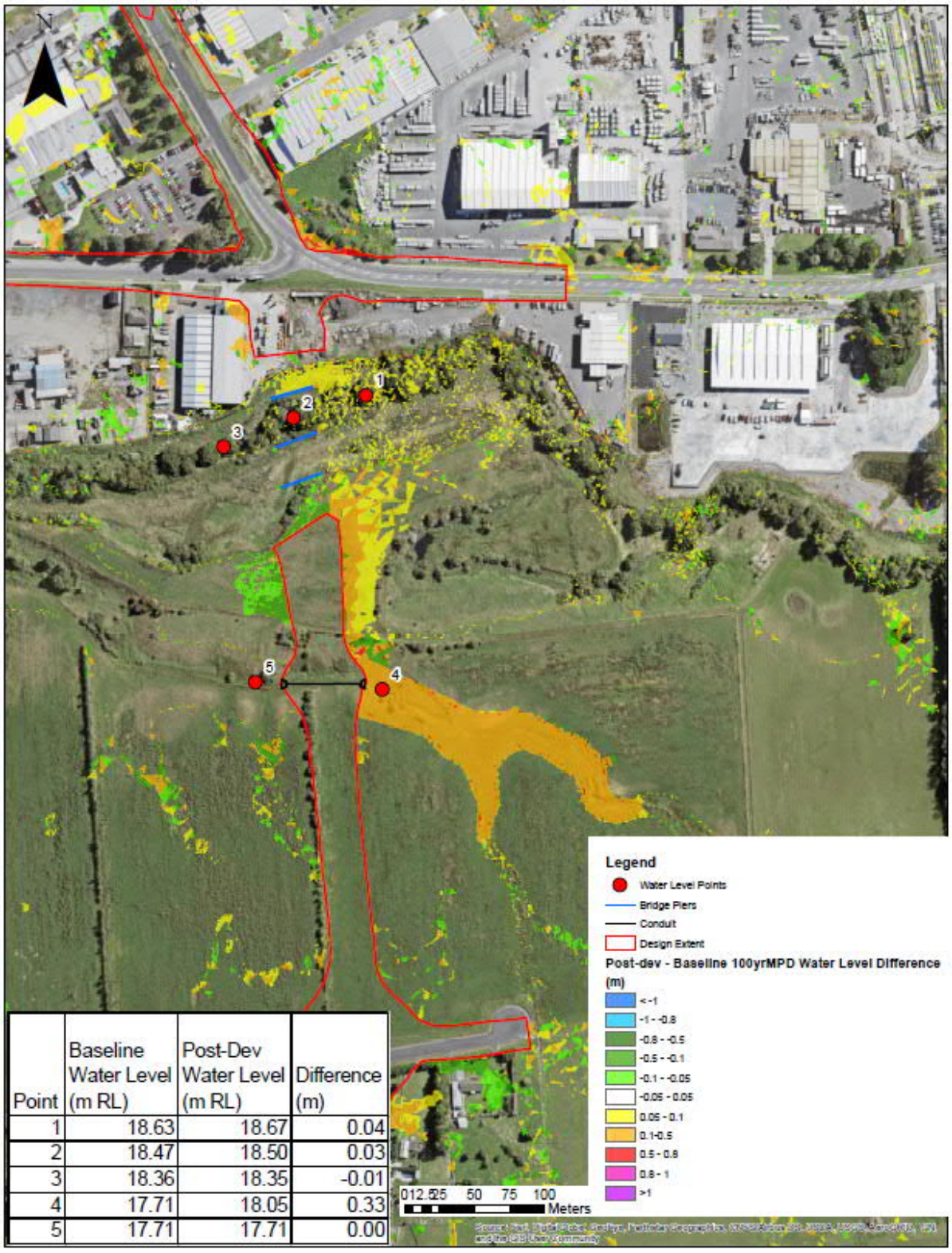
8.3.3.1 Waipokapū Stream Bridge

The proposed 120 m Waipokapū Stream Bridge has four 30 m spans across an existing 80 m wide 100 year ARI flood plain with bridge piers set outside the main river channel.

The results for the 100 year ARI pre-project development scenario show that the water level at the location of the proposed bridge structure is RL 18.63 m upstream and RL 18.36 m downstream (refer to points 1 and 3 on Figure 8-2). The results for the post-project development scenario have the water level increasing to RL 18.67 m (+0.04 m) upstream and decrease to RL 18.35 m (-0.01 m) downstream (refer to points 1 and 3 on Figure 8-2). The structure has a freeboard of at least 1.09 m between the 100 year ARI flood level and bridge soffit. There are no effects on any nearby buildings and the increases in flood level are limited to pasture and the edge of the adjacent industrial yards. Overall the effects of the bridge on flood hazards are considered minor.

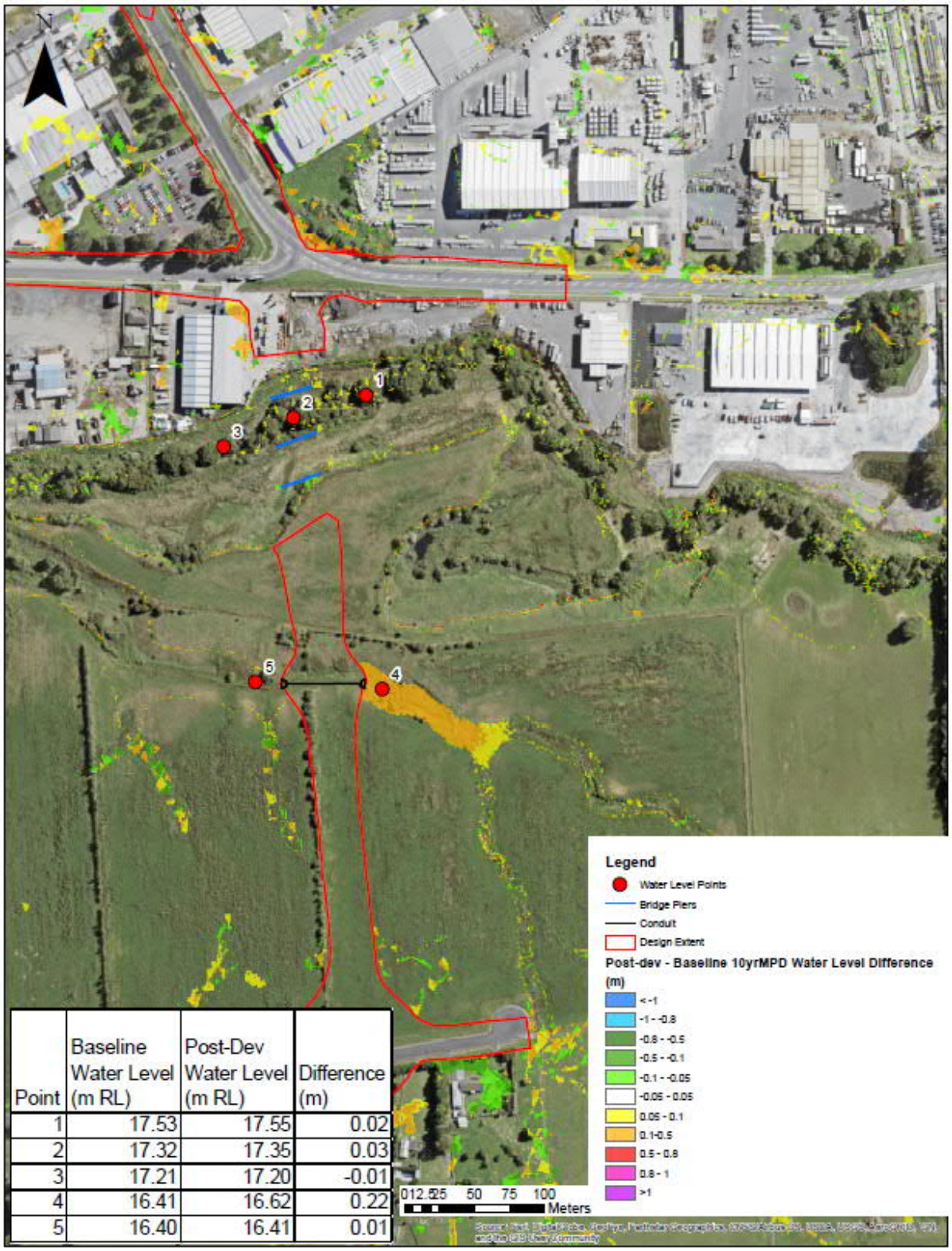
The northern approach for the bridge abutment is set above existing ground level and may cause local flooding of industrial buildings/properties on the eastern side of the abutment.

South of the bridge, a local depression will flood due to the proposed eastern road embankment obstructing overland flow from running down to the south west (see orange shading west of point 3 in the Figure 8-4 below).



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	18.63	18.67	0.04
2	18.47	18.50	0.03
3	18.36	18.35	-0.01
4	17.71	18.05	0.33
5	17.71	17.71	0.00

Figure 8-2: 100 Year flood difference map for post- minus pre-project development at Ōpāheke N-S FTN Arterial and Waipokapū Stream crossing



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	17.53	17.55	0.02
2	17.32	17.35	0.03
3	17.21	17.20	-0.01
4	16.41	16.62	0.22
5	16.40	16.41	0.01

Figure 8-3: 10 Year flood difference map for post- minus pre-project development at Ōpāheke N-S FTN Arterial and Waipokapū Stream crossing

8.3.3.2 Waipokapū Stream tributary

The proposed arterial transport corridor includes a new 3.0 x 1.5m box culvert at chainage 1500m for flood conveyance.

The results for the 100 year ARI pre-project development scenario show that the water level at the location of the proposed bridge is RL 18.77 m upstream and RL 18.32 m downstream. The results for the 100 year ARI post-project development indicate that the water level increased to RL 19.56 m (+0.79 m) upstream. This result was obtained using a 1D calculation using Culvert Master.

There are no effects on any nearby buildings due to the crossing, and the increases in flood level are currently limited to pasture areas. However, with future urban development, the current level of the corridor would create a flood prone area.

Nearby, an area of local ponding occurs against the embankment at 105 Walker Road (refer point 3 in Figure 8-4).

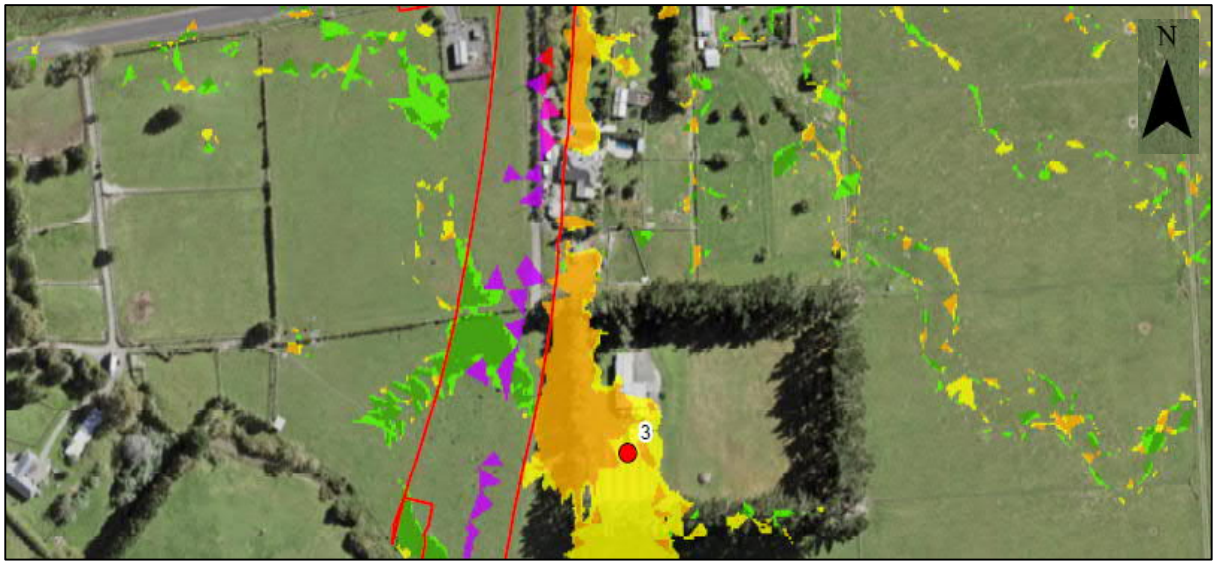


Figure 8-4: 100 Year flood difference map for post- minus pre-project development at Ōpāheke N-S FTN Arterial north of Waipokapū Stream tributary crossing

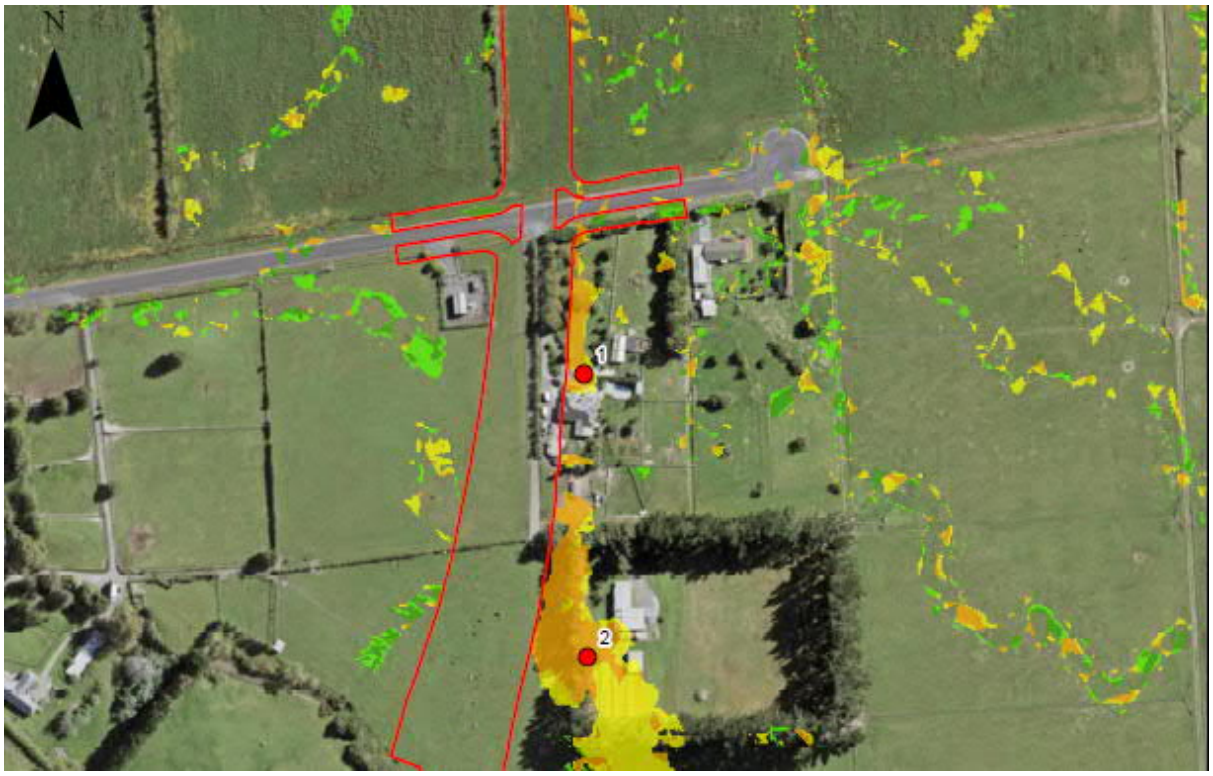


Figure 8-5: 10 Year flood difference map for post- minus pre-project development at Ōpāheke N-S FTN Arterial north of Waipokapū Stream tributary crossing

8.3.3.3 Waihoehoe Stream viaduct

The proposed transport corridor proposes a new bridge over the approximately 690 m wide flood plain at Waihoehoe Stream. Two bridge structures have been assessed in the flood modelling – a seven span 245m spanned structure and an eight span 285 m spanned structure. The 285m version avoided the need for a 2700 dia culvert at ch3040m. A 265 m intermediate version of the bridge is shown on the layout drawings. The model results presented in this section are for the 285 m long bridge structure with bridge piers outside the main river channel.

South of chainage 3000m, and south of the southern bridge abutment, the engagement with Oyster Capital Ltd has resulted in a shift to the route alignment approximately 100m to the east.

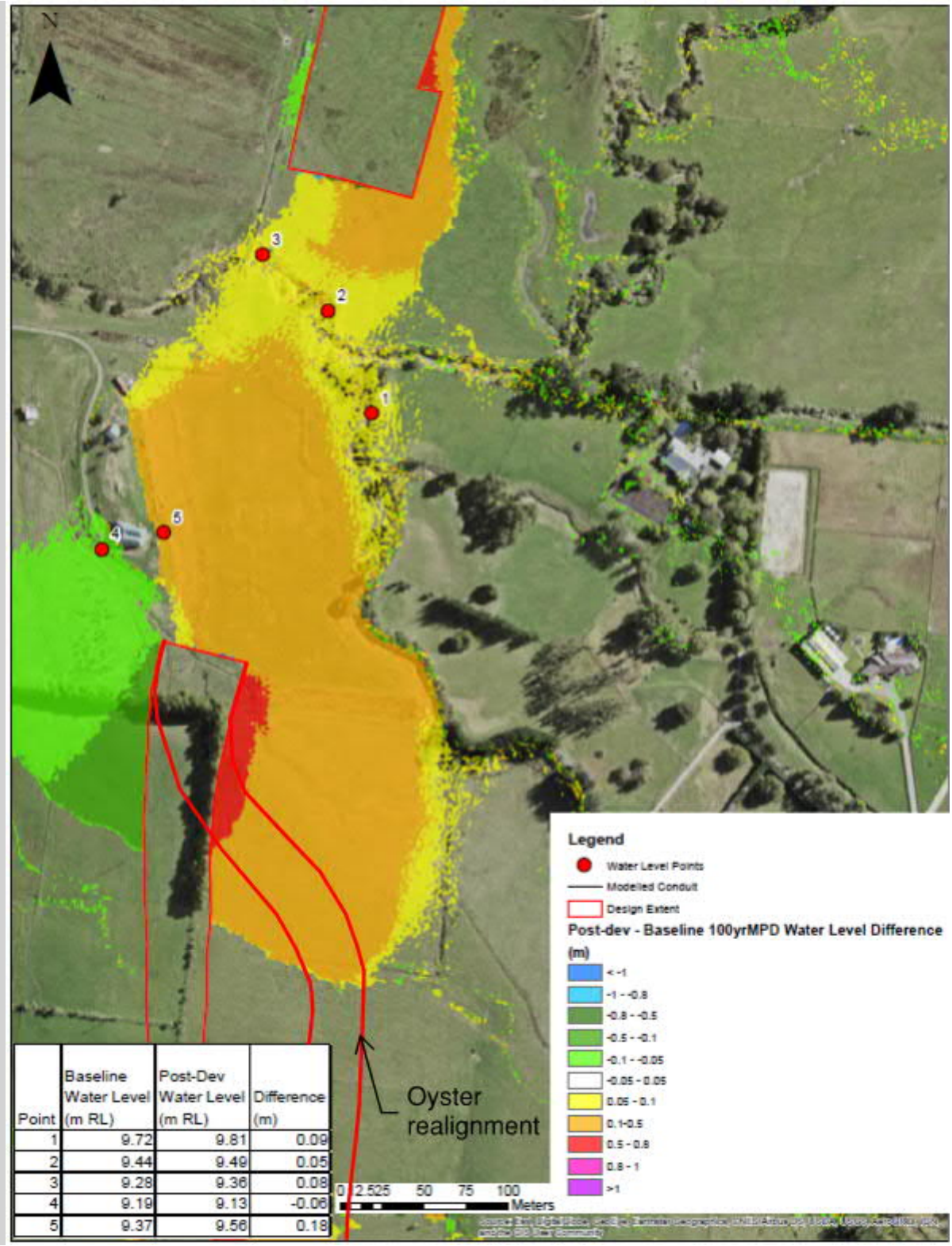
The results for the 100 year ARI pre-project development scenario show that the water level at the location of the viaduct is RL 9.72 m upstream and RL 9.28 m downstream. The results for the 100 year ARI post-project development scenario indicate that the water level increased upstream to RL 9.81 m (+0.09 m) and downstream to RL 9.36 m (+0.08 m).

It is expected that more detailed modelling would be undertaken at future design stages to confirm effects for the actual bridge geometry as that is developed further. The results presented here show that the flood effects of the bridge can be managed to acceptable levels.

The 100 year and 10 year flood results are shown on Figure 8-6 and Figure 8-7 below.

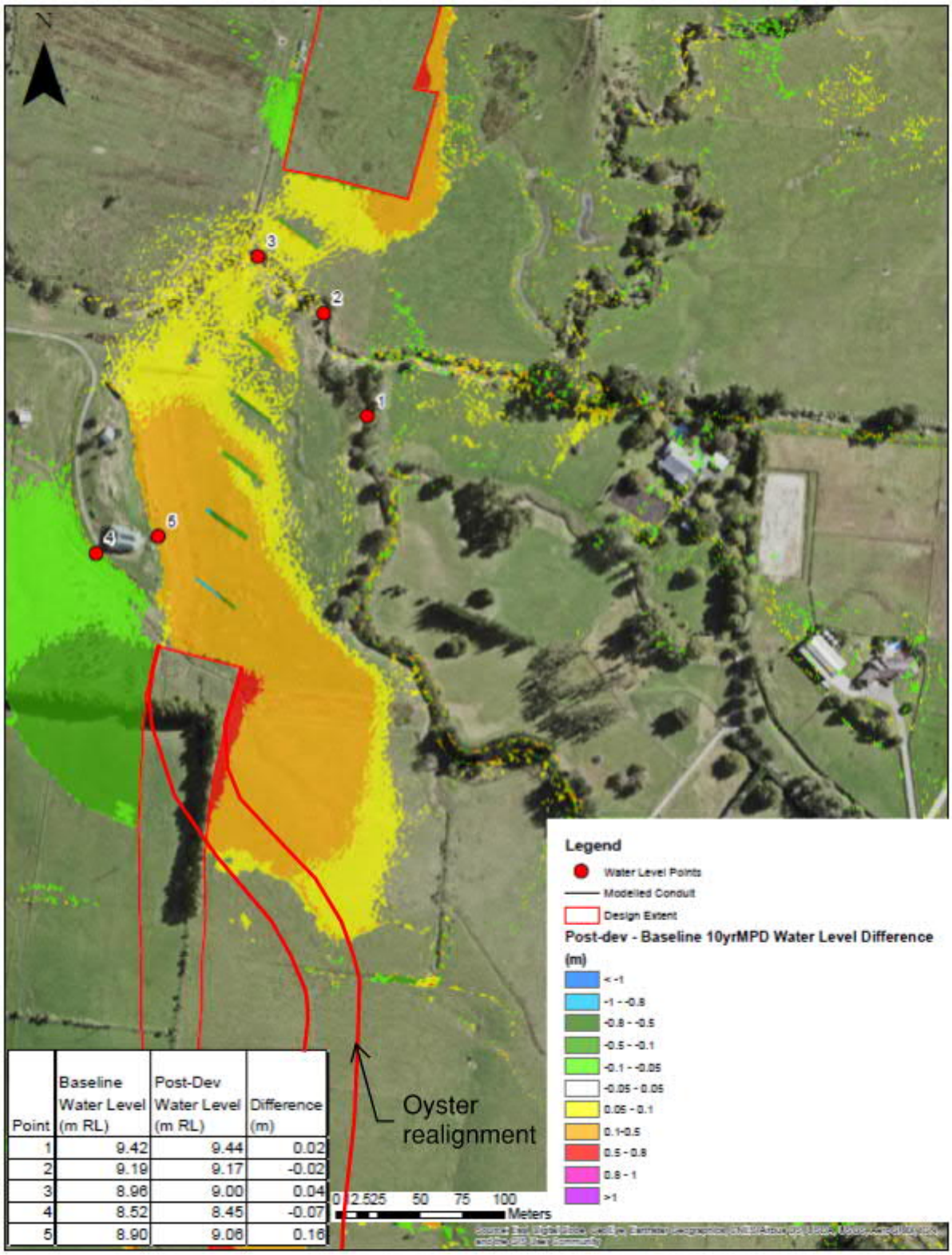
The figures below show the difference between the post-and pre-project development water levels. The increase in the 100 year ARI water level is between 100 and 250 mm in the orange shading area upstream of the main viaduct spans. No change in water levels greater than 50 mm is identified for the properties with existing flooding problems at Harry Dodd Road (this is discussed further below). An increase in upstream water level is identified south of the viaduct opening (refer Figure 8-6 and Figure 8-11). This is considered to be a local effect due to an overland flow path being blocked by the embankment. The water level increase shown in red, east of the embankment, is largely contained within the designation boundary and a diversion drain can mitigate this by diverting flows toward the main flood plain to the north.

The revised Oyster Capital alignment south of the southern bridge abutment is within a shallower and lower velocity area of the modelled flood plain (refer figures 8-9, 8-10 and 8-13).



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	9.72	9.81	0.09
2	9.44	9.49	0.05
3	9.28	9.36	0.08
4	9.19	9.13	-0.06
5	9.37	9.56	0.18

Figure 8-6: 100 Year flood difference map for post- minus pre-project development at Ōpāheke N-S FTN Arterial and Waihoehoe Stream crossing



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	9.42	9.44	0.02
2	9.19	9.17	-0.02
3	8.96	9.00	0.04
4	8.52	8.45	-0.07
5	8.90	9.06	0.16

Figure 8-7: 10 Year flood difference map for post- minus pre-project development at Ōpāheke N-S FTN Arterial and Waihoehoe Stream crossing

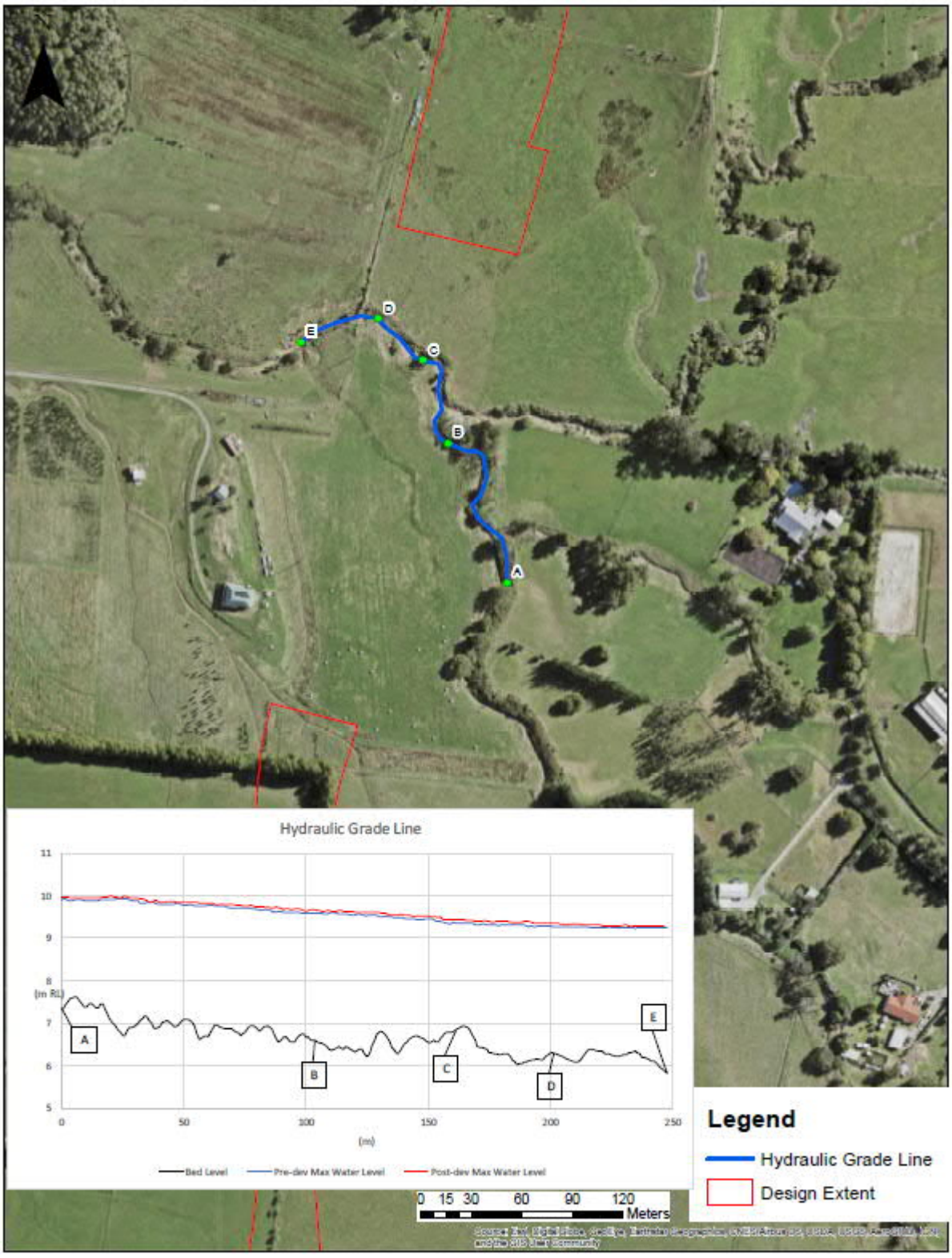


Figure 8-8: Hydraulic grade line (100 year ARI) at Ōpāheke N-S FTN Arterial and Waihoehoe Stream crossing

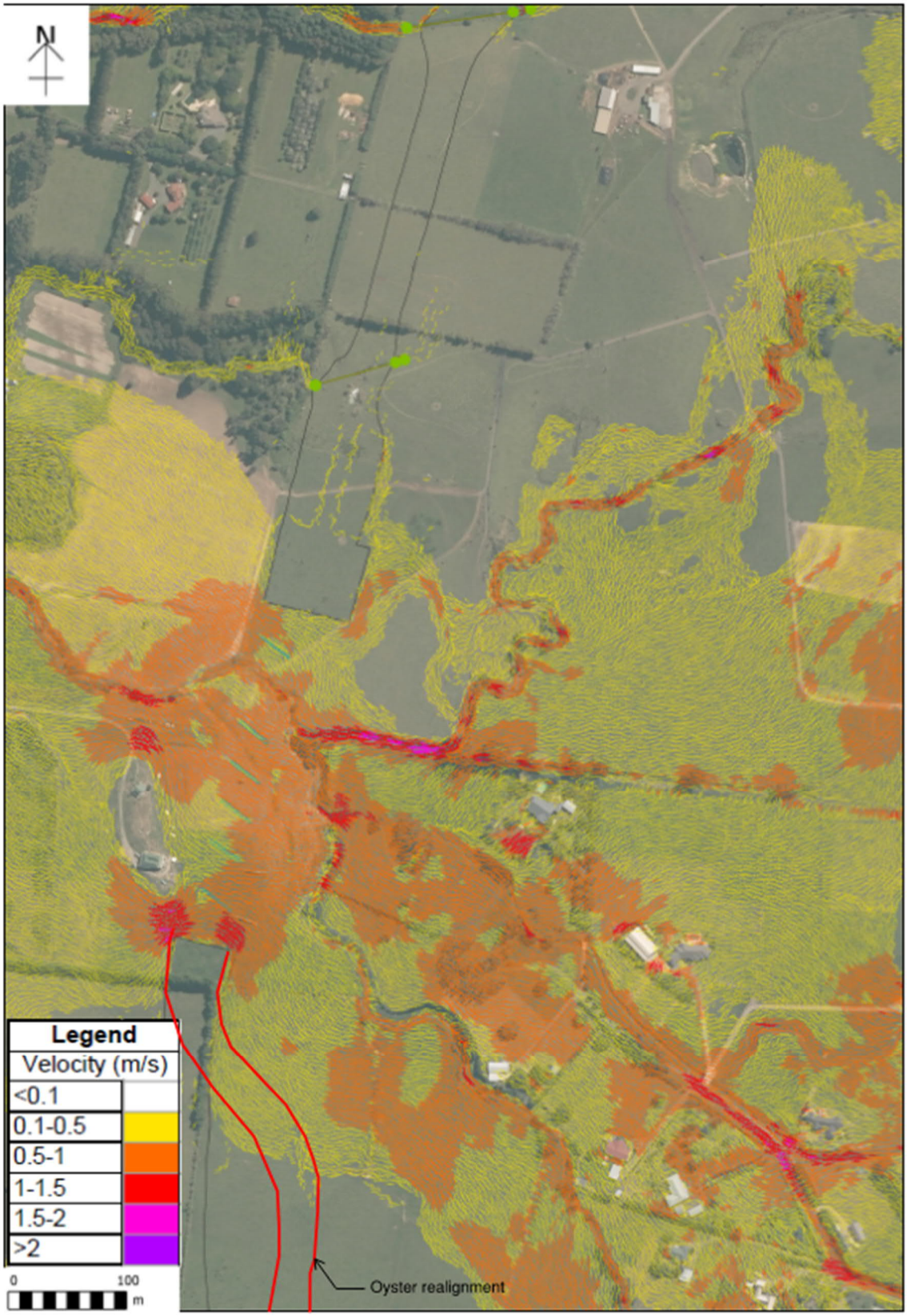


Figure 8-9: 100 Year ARI velocity vector map at Waihoehoe Stream crossing

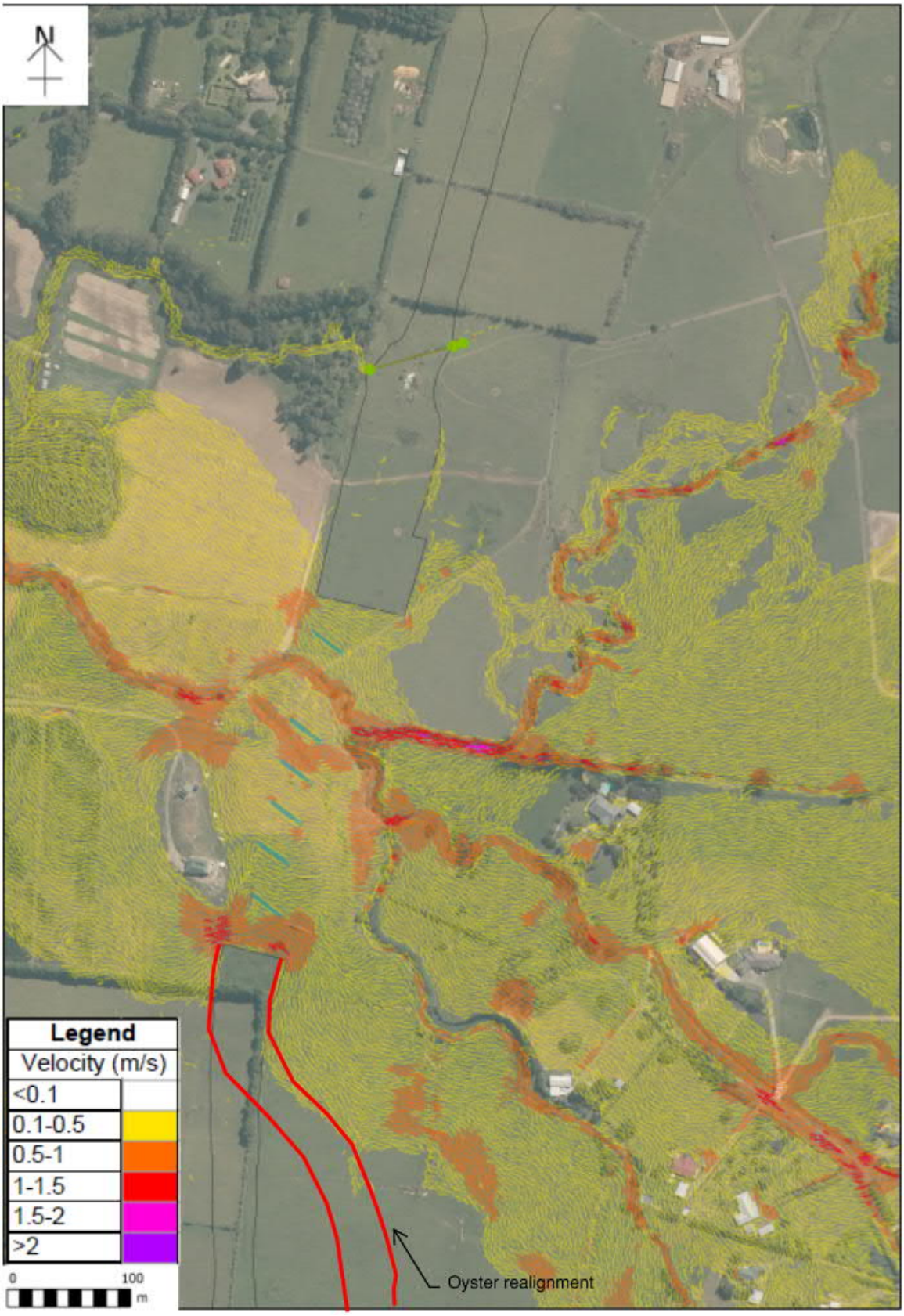


Figure 8-10: 10 Year ARI velocity vector map at Waihoehoe Stream crossing

8.3.3.4 New culvert crossings

Table 8-3 summarises the proposed culvert crossings. The existing and future flood levels indicate that most of the culvert crossings will cause an increase in water levels upstream and a decrease in water levels downstream of the crossings. The culverts may create an obstruction to the flow and due to inlet control conditions, peak flow would be reduced at the downstream end. The potential flooding effects due to the new culverts are summarized in Table 8-4 below. The specific flood levels noted in Table 8-4 are shown as the red points on figures Figure 8-2 to Figure 8-7.

Note that the flood model results for the culverts at chainages 3380, 3500 and 3680m show that water builds up at the culvert inlets. Moving the alignment to the east as agreed with Oyster Capital Ltd is expected to limit the increase in flood levels as water will overflow to adjoining land at a lower level. The culvert at chainage 3500m is no longer required.

Table 8-4: Flooding effects due to modelled culvert crossings along Ōpāheke N-S FTN Arterial

Chainage	Property address	Affected Area	Modelled Cross drainage	Existing flood level (MPD + CC) (RL)	Future flood level (MPD + CC) (RL)	Depth difference for 100-year post minus pre-project development	Assessment
chainage 930 **Road level 19.53**	164, 168, 174 Walker Road	Rural land, no buildings. FUZ	2000mm dia. culvert. Road design level 19.6	100 year ARI rainfall event: 17.71m upstream, 17.71m downstream	100 year ARI rainfall event: 18.05m upstream, 17.71m downstream	+ 0.33m upstream; 0.0m downstream	Refer Figure 8-2, point 4. Increase in flood level less than 500mm; no buildings upstream, minor effect.
chainage 1500 **Road level at chainage 1200 (Walker Road intersection) 20.97**	105 Walker Road	Rural land, no buildings. FUZ	3.0 x 1.5m box culvert	100 year ARI rainfall event: 18.77m upstream	100 year ARI rainfall event: 19.56m upstream	+ 0.79m upstream	Increase in flood level greater than 500mm. Potentially moderate effect, but no buildings affected upstream. Upsize culvert / improve inlet to reduce effect if required.
chainage 1940	61 Ponga Road	Rural land, no buildings. FUZ.	1650mm dia. culvert Road design level 24.1	100 year ARI rainfall event: 21.0m upstream, 18.22m downstream	100 year ARI rainfall event: 22.38m upstream, 18.06m downstream	+ 0.63m upstream; - 0.16m downstream	Refer Figure 8-11, point 0. Increase in flood level greater than 500mm. Potentially moderate effect, but mostly within designation. No buildings upstream. Upsize culvert / improve inlet to reduce effect.
chainage 2220 **Road level 20.8**	61 Ponga Road	Rural land, buildings. FUZ.	2000mm dia. culvert Road design level 20.6	100 year ARI rainfall event: 16.53m upstream, 15.02m downstream	100 year ARI rainfall event: 16.99m upstream, 14.97m downstream	+ 0.48m upstream; - 0.11m downstream	Refer Figure 8-11, point 2. Increase in flood level greater than 500mm. Potentially moderate effect but confined to existing gully. No flood level increase to buildings upstream.

Chainage	Property address	Affected Area	Modelled Cross drainage	Existing flood level (MPD + CC) (RL)	Future flood level (MPD + CC) (RL)	Depth difference for 100-year post minus pre-project development	Assessment
							Upsize culvert to reduce effect. Mitigate potential culvert blockage effects by providing an overland flow path to the south.
chainage 2520	61 Ponga Road	Rural land, no buildings. FUZ.	1650mm dia. culvert Road design level 17.6	100 year ARI rainfall event: 17.06m upstream, 9.51m downstream	100 year ARI rainfall event: 17.50m upstream, 9.41m downstream	+ 0.45m upstream; -0.13m downstream	Refer Figure 8-11, point 4. Increase in flood level greater than 500mm, but likely to be within designation. No flood level increase to buildings upstream. Upsize culvert or provide an overland flow path to the south to reduce effect if required.
chainage 3380 **Road level at chainage 3140m sag 10.62**	116 Waihoehoe Road	Rural land, no buildings. FUZ.	1650mm dia. culvert Road design level 14.2				Refer Figure 8-12. Increase in flood level less than 500mm. Potential effect is within pasture, and within designation. Construct diversion drain along base of embankment draining north to mitigate effects.
chainage 3500	116 Waihoehoe Road)	Rural land. FUZ.	Culvert is no longer required due to alignment shift to the east				Refer Figure 8-12. Increase in flood level less than 500mm. Potential effect within pasture, within designation. Construct diversion drain along

Chainage	Property address	Affected Area	Modelled Cross drainage	Existing flood level (MPD + CC) (RL)	Future flood level (MPD + CC) (RL)	Depth difference for 100-year post minus pre-project development	Assessment
							base of embankment to mitigate effects.
chainage 3680	136 Waihoehoe Road	Rural land, no buildings. FUZ.	1950mm dia. culvert Road design level 17.1				Refer Figure 8-12. Existing ornamental pond/dam. Increase in flood level 50 to 500mm. Potential minor effect within pasture, within designation. Construct diversion drain along base of embankment to mitigate effects.

A number of existing culverts (refer to Figure 8-11 and Figure 8-12 below) have water build up at their inlet in order to provide enough head for the culvert to operate and pass the 100 year flow. This is normal operation for culverts and in most cases does not cause any effects apart from local ponding on surrounding pasture. In the future, if urban intensification occurs prior to construction of the corridor nearby, the increases in flood level at the culvert inlets may be of greater concern due to the height of the headwater pool or extent of land occupied, in which case a larger culvert can be used to reduce the amount and level of ponding.

In these cases, the consequences of the culvert blockage need to be considered further with, for example, overland flow through open space being of low consequence and ponding affecting a habitable building of high consequence. Based on existing terrain the culvert inlets at chainage 1940 (western side) and chainage 930, 1500, 2200, 2500 and 3680 (eastern side) are at risk in this way. However, with urban development the terrain is likely to be regraded and with good subdivision design, the risk could be reduced. Based on a qualitative review of the risk (based on the current upstream terrain and size of catchments leading to these culvert inlets) it is considered that overall the risk of culvert blockage is relatively low and that there is enough space within the proposed designation to accommodate overland flow paths or secondary inlets to mitigate the risk if required.

In a few places, the proposed road embankment level is above the upstream land, which cuts off overland flow and forms a new flood prone area on the eastern side of the embankment (for example, at chainage 570, 1400, 1900, 3040, 3680). Only one of these flood prone areas may affect an existing property/building – at chainage 1400. This increase in local flood water depth could be mitigated by the construction of a diversion drain along the eastern embankment to allow flood water to escape to a lower elevation or a larger culvert and secondary inlets provided within the designation. Diversion drains such as this are recommended at chainage 1300-1500, 1850-1980, 3050-2920 and 3670-3300.

An alternative approach may also be possible where earthworks upstream increase the building platform levels so that they are no longer at risk of flooding. This however depends upon the specific layout and levels of upstream developments and it is unknown whether it is feasible at this stage.

Overall it is considered the flood risk of culvert blockage can be mitigated by constructing overland flow paths and secondary inlets witihn the proposed designation footprint. It is recommended the culvert blockage and mitigation details are considered further at the detailed design phase.

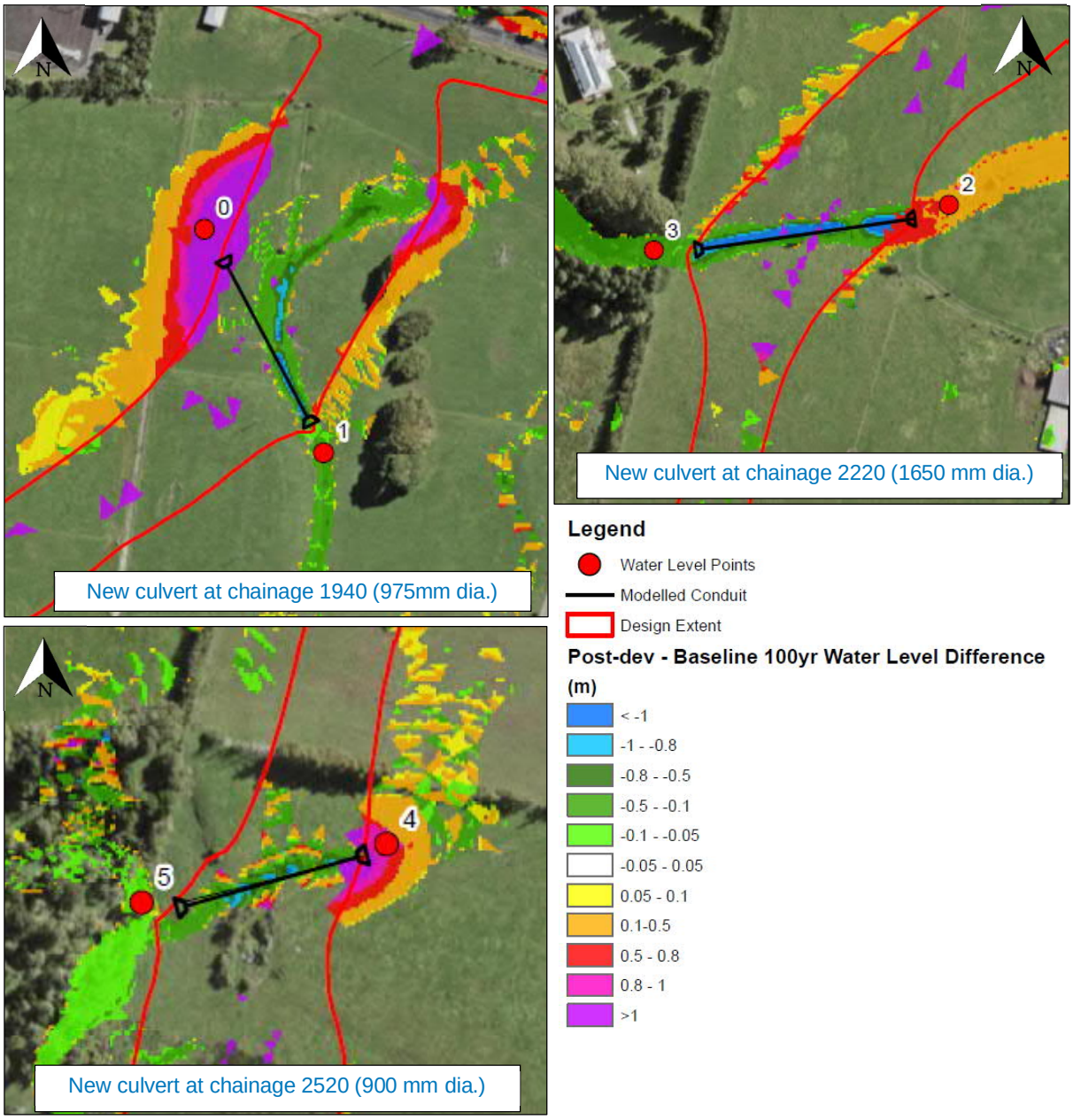


Figure 8-11: 100 Year flood difference map for post -minus pre-project development at Ōpāheke N-S FTN Arterial northern culvert crossings

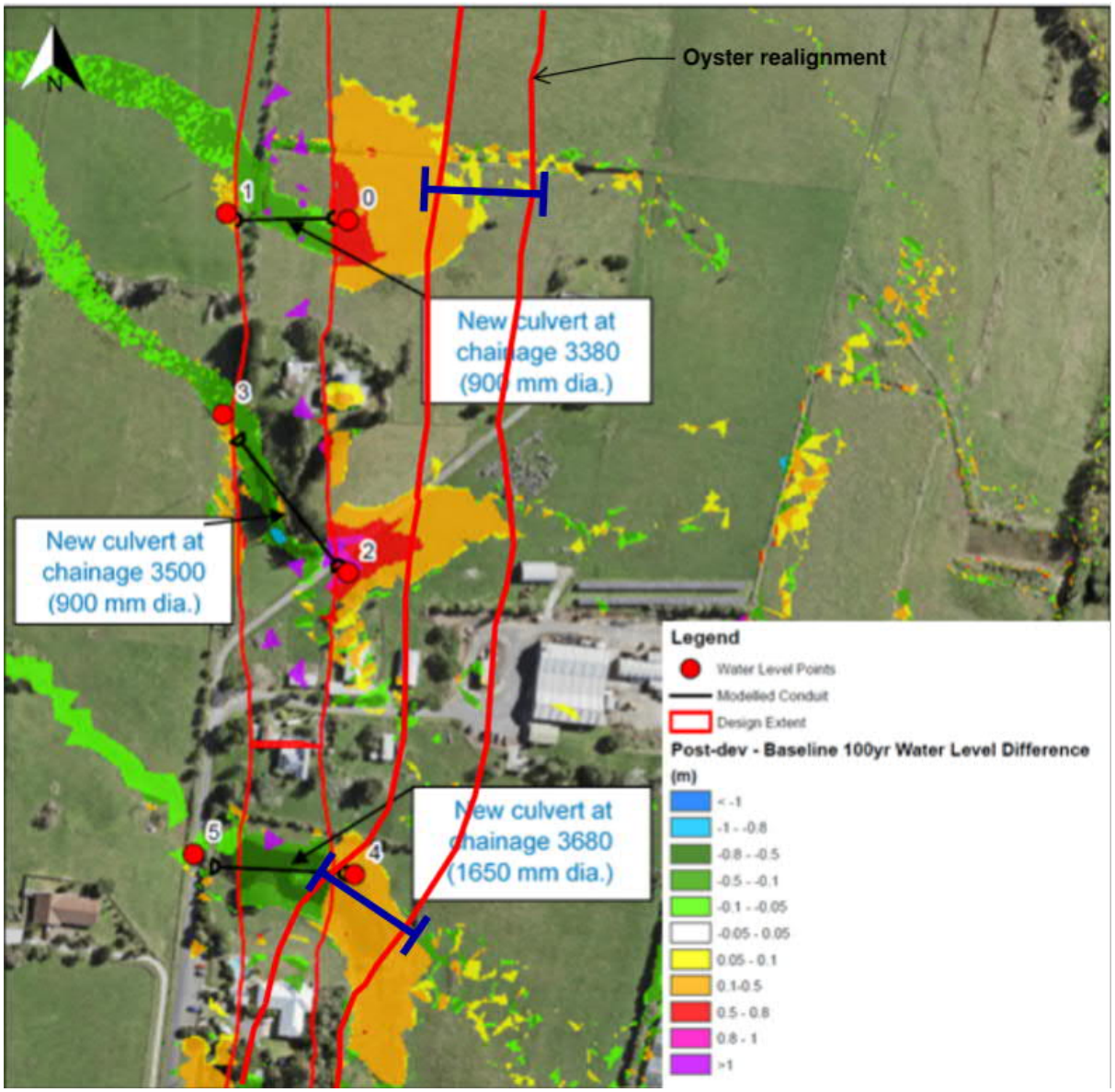


Figure 8-12: 100 Year flood difference map for post -minus pre-project development at Ōpāheke N-S FTN Arterial southern culvert crossings

8.3.3.5 Property Assessment

According to the Auckland Council Modelling Specification a freeboard of 500 mm should be added on top of the 100 year ARI MPD flood level for habitable floor levels to have adequate freeboard and be safe for use. Building floors potentially affected by the flood hazards are counted either as being below the 100 year flood level or within 500 mm of the 100 year flood level. Driveways and parking areas should be kept safe from flooding with allowable water depths below 150 mm for cars and 300 mm for trucks.

105 Walker Road, east of the embankment at chainage 1400 (refer to point 3 in Figure 8-4), is affected by an increase in flooding due to the embankment blocking an overland flow path that would have drained away to the south west.

An existing flooding area upstream of the Waihoehoe Stream crossing in the vicinity of Harry Dodd Road was identified as at potential risk to increased flooding. Five properties were identified as shown in

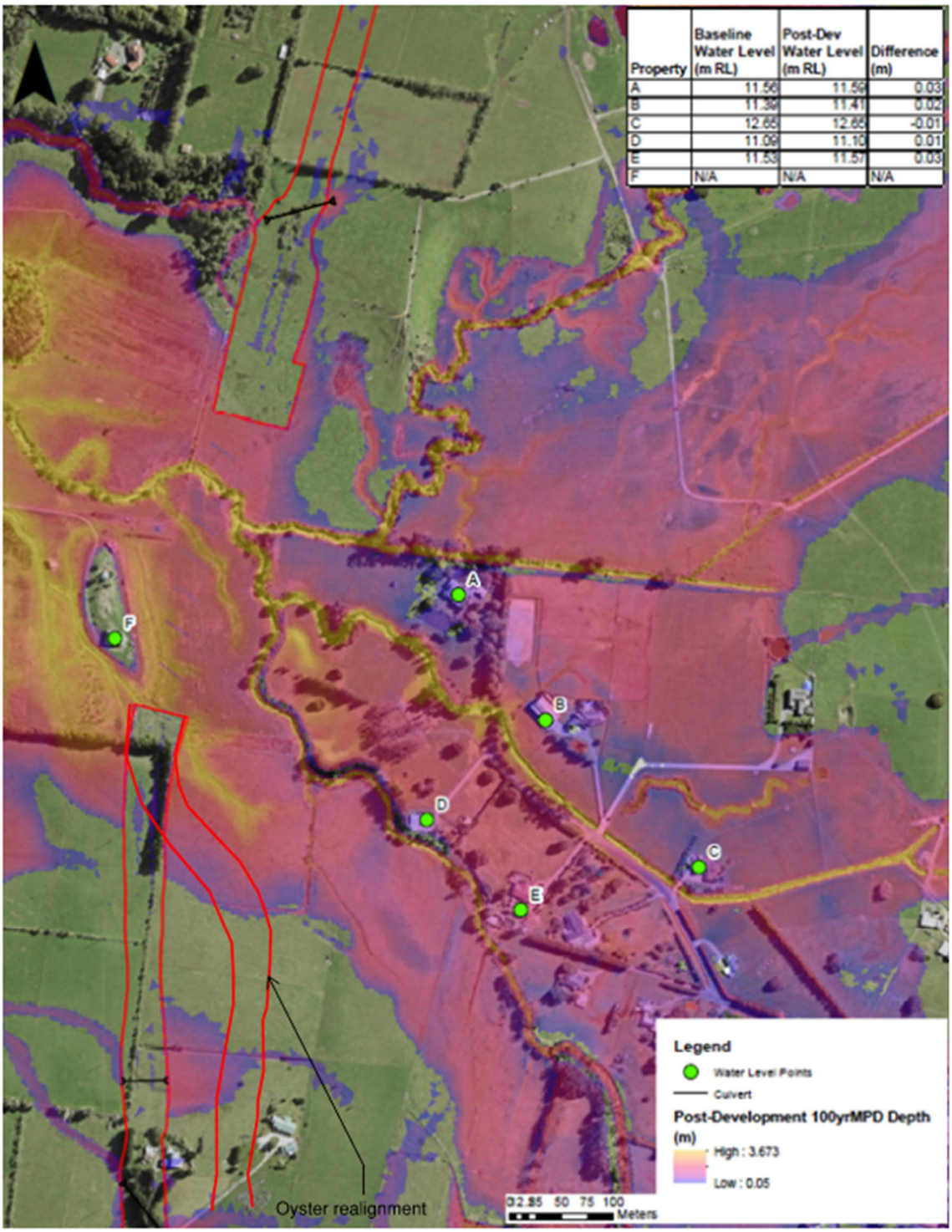


Figure 8-13. The post minus the pre-project development water level differences at these properties are all below 50 mm, which is considered a minor effect.

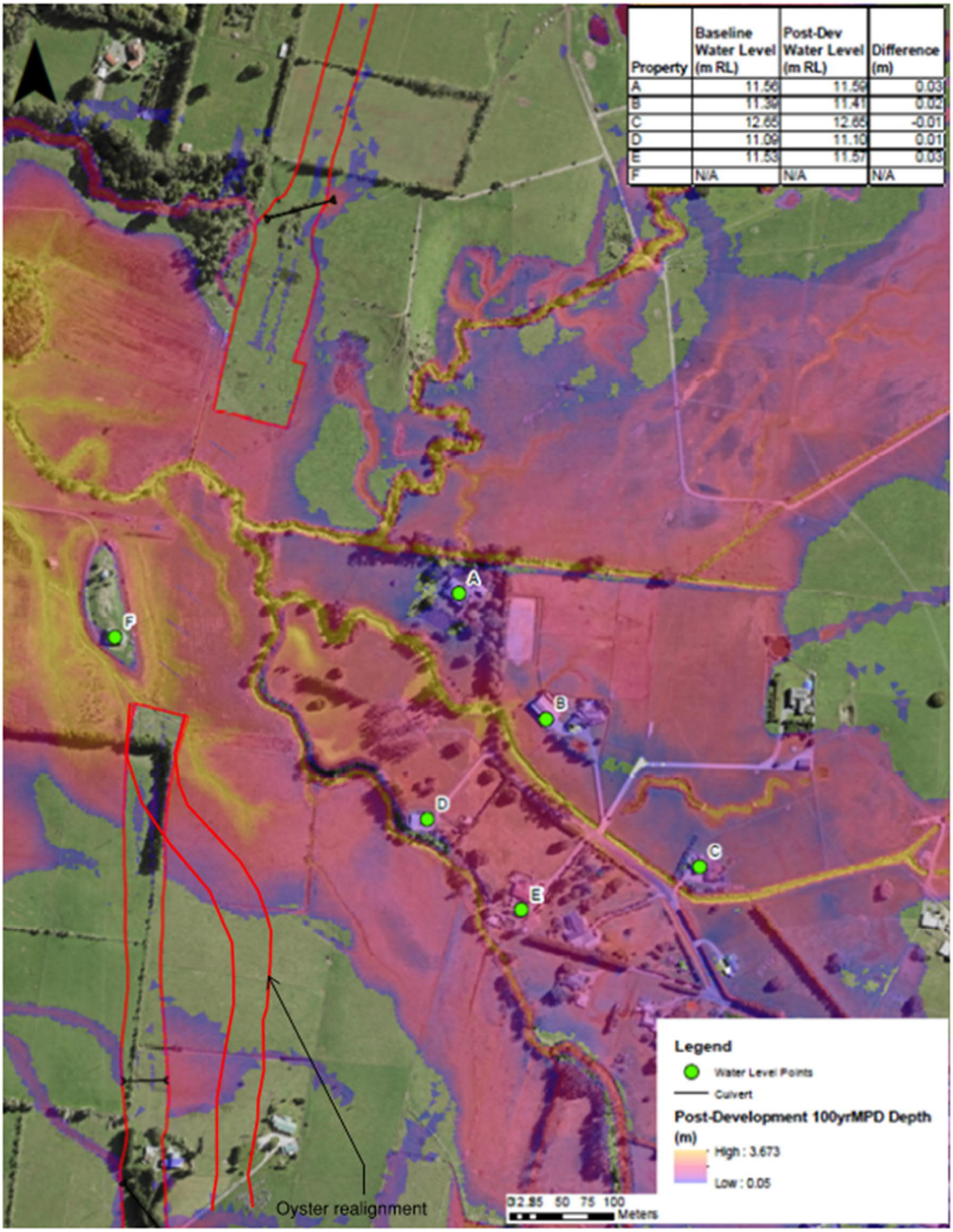


Figure 8-13: Property assessment locations upstream of Ōpāheke N-S FTN Arterial and Waihoehoe Stream crossing

Table 8-5: Properties potentially at risk of flooding along Ōpāheke N-S FTN and surrounds

Point on difference map	Property address	Affected area	Water level difference for 100-year post minus pre-project development	100-year flood level (RL)	Comments
Point 3 in Figure 8-4	105 Walker Road, Drury	Building, site levels RL 20.0	+ 0.09m	Pre-dev:20.07m Post-dev:20.16m	Diversion drain required to minimise increase in flood level.
Property A	103 Harry Dodd Road, Drury	Building / house, site levels RL11.0 to 11.5m, floor level assumed 0.5m off ground	+ 0.03m	Pre-dev:11.56m Post-dev:11.59m	Increase in flood level less than 50mm; minor effect
Property B	89 Harry Dodd Road, Drury	Building / house, site levels RL11.5m, floor level assumed 0.5m off ground	+ 0.02m	Pre-dev:11.39m Post-dev:11.41m	Increase in flood level less than 50mm; negligible
Property C	59 Harry Dodd Road, Drury	Building / house, site levels RL12.0m floor level assumed 0.25m off ground	0.00m	Pre-dev:12.65m Post-dev:12.65m	No effect
Property D	106 Harry Dodd Road, Drury	Building / house, site levels RL10.0m to 10.5m, floor level assumed 0.5m off ground	+ 0.01m (based on original route alignment – approx. 210m away)	Pre-dev:11.09m Post-dev:11.10m (based on original route alignment – approx. 210m away)	Closest existing dwelling to revised (Oyster) alignment – approx. 140m away. Increase in flood level less than 50mm; minor effect.
Property E	100 Harry Dodd Road, Drury	Building / house, site levels RL10.5m to 11.0m, floor	+0.04m	Pre-dev:11.53m Post-dev:11.57m	Increase in flood level less than 50mm; minor effect

Point on difference map	Property address	Affected area	Water level difference for 100-year post minus pre-project development	100-year flood level (RL)	Comments
		level assumed 0.5m off ground			
Property F	201 Sutton Road, Drury	Building / house, site levels RL10.0m approx., floor level assumed 0.75m off ground	+ 0.18m	Pre-dev:9.37m Post-dev:9.56m	Increase in flood level more than 50mm, with freeboard assumed greater than 500mm; minor effect

Note that the existing freeboard for properties at Harry Dodd Road are assumed to be less than 500mm and therefore, for flood level increases of less than 50mm the effects are considered minor.

8.3.4 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The proposed bridges over the Waipokapū and Waihoehoe Streams are appropriate methods to manage flood hazard effects. Further flood modelling will be required to confirm bridge arrangements and their effects on adjoining properties. Coordination of requirements with upstream develpoment plans is also recommended.

Diversion drains are likely needed on the eastern embankment for the bridge abutment over Waipokapū Stream. These would prevent localised ponding against the embankment which may affect industrial properties and a building at 70 and 72 Hunua Road (on the north-east quadrant of the intersection with Hunua Road).

North of the culvert over the Waipokapū Stream tributary, a local flood prone area will be formed due to the eastern side of the road embankment obstructing overland flow from running down to the south west. A diversion channel at the base of the eastern embankment from chainage 1275 to 1500 will drain this local ponding area toward the proposed culvert and prevent an increase in flood levels to the existing property. Measures to mitigate culvert blockage are required.

In a few places, new culverts head up and the nearby road embankment cuts off overland flow and forms a new flood prone area on the eastern side of the embankment (for example chainage 1900, 3040). Diversion drains are recommended at chainage 1850-1980, 3050-2920 and 3670-3300 to prevent these flood prone areas forming and reduce local flood levels.

In the future, there is a risk of flooding due to culvert blockage at new flood prone areas (where local depressions are created by the arterial road embankment). It is considered likely that there is space

within the designation to mitgate this risk by providing overland flow paths or secondary inlets. The level of flooding risk and mitigation details will need further assessment at the detailed design stage.

8.4 Conclusion

The construction activities of the Ōpāheke N-S FTN Arterial include new culverts, new bridges and wetlands with the potential to affect the Waihoehoe and Waipokapū Streams and their tributaries. Temporary watercourse diversions will be suitable for the majority of the culvert construction. The bridges can be constructed from outside the main channels. Flow management, staging and consideration of flood hazards in the CEMP will be critical for works within the larger Waihoehoe Stream flood plain.

The operational effects refer to the existing (pre-project development) and future (post-project development) flood model results and considers the flooding extents at new culvert crossings, bridge crossings over Waipokapū Stream and Waihoehoe Stream and the flooding extents on existing properties due to the new transport corridor. The property assessment in Table 8-5 summarises the properties with existing habitable buildings where potential flood effects have been identified – with all these potential effects considered minor or negligible. The culvert assessment in Table 8-4 summarises the potential effects of culverts heading up - with a number of locations identified where the increase in flood water height was greater than 500 mm on other property and is therefore potentially moderate. However all of these increases were contained to existing pasture areas, did not affect existing buildings and are considered potential effects which can be mitigated by diversion drains, increasing culvert sizes and/or managing the potential for inlet blockage within the proposed designation extent or integrating corridor and upstream development design requirements (e.g. building platform and road levels).

The risk of culvert blockage and the potential effects will need to be considered further at detailed design stage, however it is considered mitigation measures will be able to be implemented within the proposed desigation extent

8.4.1 Recommendations for NoR D4 conditions

Construction effects

It is recommended that a CEMP be developed prior to construction. The CEMP shall consider and mitigate potential adverse flood hazard effects. The flood hazard effects shall be assessed by an experienced Stormwater Engineer and shall consider the effects of temporary works, earthworks, storage of materials and temporary diversion and drainage on flow paths, flow depth and velocity.

Operational effects

It is recommended that detailed design should demonstrate that:

(a) The Waipokapū Stream (Hays Stream) located at NZTM 1774695, 5894749 is crossed by a bridge

(b) The Waihoehoe Stream located at NZTM 1774170, 5892784 is crossed by a bridge

It is recommended that during detailed design, that flood modelling of the pre project and post project 100 year ARI flood levels (both for MPD land use and including climate change) is carried out and measures implemented to achieve the following outcomes:

1. 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)
2. 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)
3. 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
4. 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)
5. that there is no more than a 10% average increase of flood hazard (defined as flow depth times velocity) for main access to authorised habitable dwellings.

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

9 NoR D5: Ponga Road and Ōpāheke Road Upgrade

Chapter Summary

NoR D5 includes upgrading Ponga Road and Ōpāheke Road rural sections to a two lane arterial with separated walking and cycling. NoR D5 also includes upgrading the Ōpāheke Road/Settlement Road intersection to provide for upgraded cycling facilities. The remainder of Ōpāheke Road within the urban area has not been assessed as the cycle lane is to be located within the existing berm.

The Ponga Road section consists of the widening the existing Ponga Road to enable a two-lane arterial from the proposed intersection with Ōpāheke N-S FTN Arterial in the west, to near Jack Paterson Road east, tying into the future Mill Road transport corridor. The transport corridor is delineated into three sub-catchments that drain towards two proposed wetlands for stormwater management. The scope of work includes new pedestrian and cycle crossings of the Mangapū stream, raising Ponga Road to meet Mill Road, a new bridge over the Mangapū Stream to manage flooding and two new wetlands. Wetlands 1 and 2 are sized for stormwater quality treatment, retention/detention for stream health and flood attenuation.

The Ōpāheke Road Rural section involves widening the existing Ōpāheke Road to enable a two-lane arterial standard from the proposed intersection with Ōpāheke N-S FTN Arterial in the southeast, to the extent of the Future Urban Zone near Lorelei Place in the northwest. The scope of work includes new pedestrian and cycle crossings (set at the same level as the existing Ōpāheke Road Bridge) over the Ōtūwairoa Stream, a new bridge over the NIMT, diversion and creation of overland flow paths and two wetlands (one of which is an upgrade to an existing AC pond servicing the Drury Reserve). The transport corridor is delineated into three sub-catchments that drain towards the two proposed wetlands for stormwater quality treatment, retention/detention for stream health and flood attenuation.

The Ōpāheke Road Urban section involves changing the intersection to a roundabout and providing a cycle path. The scope of works would include providing stormwater treatment and flood attenuation within the proposed designation.

The existing land use along Ponga Road is rural and zoned FUZ. A few overland flow paths cross Ponga Road and a flood prone area is evident at a culvert crossing at chainage 1440m. The existing 100 year ARI flood maps from Auckland Council GeoMaps show a flood plain overtops Ponga Rd at twin 2000mm diameter culverts conveying the Mangapū Stream.

The existing land use along the Ōpāheke Road Rural section is currently rural and zoned FUZ and Open Space. The existing 100 year ARI flood maps from Auckland Council GeoMaps show a flood plain over Ōtūwairoa Stream, overtopping of the existing Ōpāheke Road Bridge and flooding of properties upstream and downstream of the bridge crossing.

There may be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridges. However, the details of the construction approach have yet to be confirmed at this time. It is expected that the works can be carried out in a way that will appropriately manage the risk and this will be defined through flood risk mitigation measures captured in the Construction Environmental Management Plan (CEMP).

Flood hazard is therefore a matter that is recommended to be addressed in the CEMP and included as a condition of the proposed designation.

The operational phase flooding effects of NoR D5 have been assessed using the difference between the existing (pre-project development terrain) and future (post-project development terrain) flood model results. Upstream flood levels will be affected by the new bridges at Ōtūwairoa Stream (at Ōpāheke Road Rural) and Mangapū Stream (at Ponga Road Upgrade).

The Project has been designed so that potential flooding effects can be appropriately managed and will be less than minor subject to the recommended design outcomes outlined in this Report. Specific design considerations to manage potential flooding effects should be considered in the following areas of the Project alignment.

Modelling has identified an increase in the flood levels upstream of the Ponga Road crossing of Mangapū Stream which may reduce access to 198 Ponga Road. However, no buildings are affected, and within 150m upstream and 80m downstream the change in flood levels is less than 50mm. It is expected that with optimisation of the bridge arrangement and span that effects on upstream flood level can be reduced so that they are minor. Further work is recommended in future design phases in this regard. Raising the road has positive effects for road users by preventing flood flows across the road and reducing flood hazard.

The flood level increase due to the new pedestrian bridges at the Ōtūwairoa Stream is +0.14m immediately upstream of the bridge and +0.11m upstream at 156 Ōpāheke Road (which has a lower floor expected to flood in the pre project scenario). It is recommended that the magnitude of the effect is confirmed at the detailed design phase and, for any existing habitable floors with more than a 10% reduction in freeboard, mitigation is provided. Mitigation could consist of increasing the span of the existing road bridge and new pedestrian /cycle bridges to reduce flooding. Raising the pedestrian and cycle bridges above the existing road bridge level is not recommended as this could create a greater obstruction to flood flows at the abutments where they tie back into existing levels. Any other new or redeveloped habitable floors upstream should be designed to account for the post development scenario.

As the new pedestrian / cycle bridges are to be constructed below 100 year ARI flood levels, a management response is recommended to be developed to manage their use during overtopping flooding events.

Overland flow path realignment east of the existing rail line, as well as embankments associated with the new NIMT grade separation bridge, will change flow paths, fill existing drains and require new drains to maintain existing flow patterns. These matters can be addressed within the proposed designation and are recommended for further work in future design phases.

Most of the land identified for future stormwater management wetlands is outside flood plains. Ōpāheke wetland 1 is an upgrade of an existing Auckland Council pond on the edge of the floodplain. This is considered low risk with further assessment of the risk of scour and overtopping and mitigation recommended for the detailed design phase.

Stormwater treatment and flow attenuation can be provided within the proposed designation for the Ōpāheke Road / Settlement Road intersection upgrade.

Overall it is considered that the flooding effects arising from the proposed designation can be appropriately mitigated and with the measures recommended are expected to be no more than minor. There is space within the designation sought for the proposed stormwater and flood management related works.

9.1 Project Description

As the Drury-Ōpāheke area is urbanised it is proposed to upgrade a 4.15km section of Ponga Road and Ōpāheke Road, from Great South Road in the north, to Jack Paterson Road and the future Mill Road corridor (which forms a separate NZUP project) in the southeast, to a two-lane arterial with separated walking and cycling facilities. The functional intent of the Project is a multimodal corridor that provides access to the proposed Mill Road corridor, FUZ in Papakura and employment areas to the north. The Project has been separated into three sections as shown in Figure 9-1.

- Ponga Road Upgrade: from Ōpāheke Road to Jack Paterson Road
- Ōpāheke Road Rural Upgrade: from the northern extent of the FUZ to Ponga Road
- Ōpāheke Road Urban Upgrade: north of the FUZ

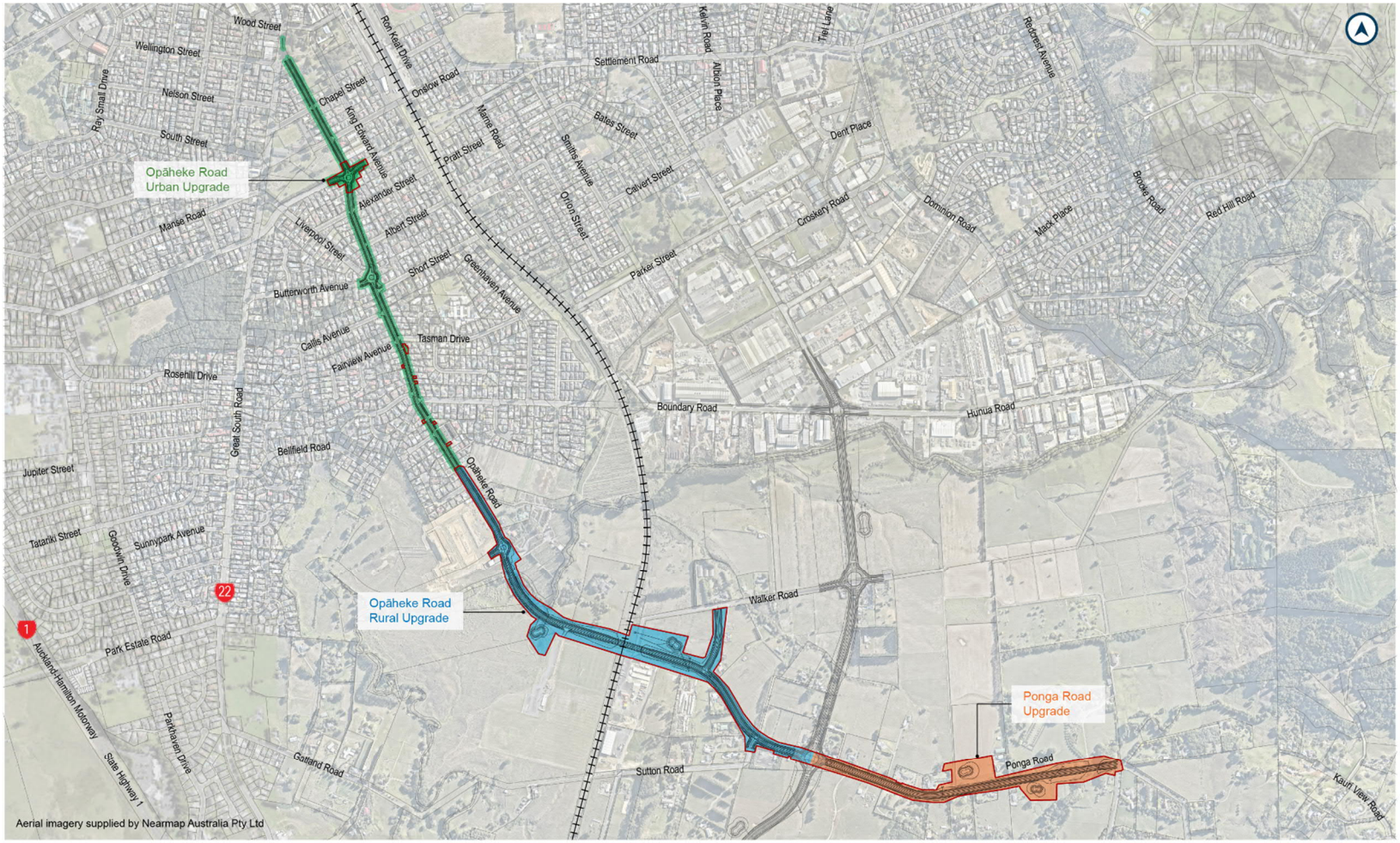
While the overall plan for the urban area of Ōpāheke Road is to upgrade the walking and cycling facilities from Ōpāheke Road Rural Upgrade in the south to Great South Road, Papakura in the north, generally, the upgrade can fit within the existing road reserve, therefore only the areas affecting land outside the existing road reserve are proposed to be designated.

For the Ponga Road and the Ōpāheke Road Rural upgrade sections it is proposed to widen the existing roads to 24m two-lane urban arterials with separated walking and cycling facilities. As the Ōpāheke Road urban section is an existing and constrained urban environment, it is proposed to upgrade the existing road to a 20m two-lane urban arterial with separated walking and cycling facilities.

The indicative alignment has been prepared for assessment purposes, and to indicate what the final design of the Project may look like. The final alignment will be refined and confirmed at the detailed design stage. Key features of the proposed upgrade common to each Project section include the following:

- A typically 24m or 20m wide road with two lanes and separated walking and cycling facilities
- Likely posted speed of 50kph
- Localised widening around the existing intersections to accommodate for vehicle stacking and tie-ins and walking and cycling facilities/crossings
- Batter slopes and retaining to enable widening of the corridor and/or wetland construction, and associated cut and fill activities
- Vegetation removal along the existing road corridor
- Areas identified for construction related activities including site compounds, construction laydown, bridge works area, the re-grade of driveways and construction traffic manoeuvring

Further details of each Project section are provided below.



Works shown for the Ōpāheke Road Urban Upgrade outside of the proposed designation boundary are indicative and will be subject to a separate statutory approvals process (if required) in the future. Only those works within the designation boundary are assessed.

Figure 9-1: Overview of NoR D5

9.1.1 Ponga Road Upgrade Section

9.1.1.1 Section Overview

The Ponga Road Upgrade section is a 1km long upgrade extending from the proposed intersection with Ōpāheke North-South FTN Arterial in the west, to Jack Paterson Road in the east. In the future Ponga Road will tie into the proposed Mill Road corridor which forms a separate NZUP project. An overview of the concept design is provided in Figure 9-2.

Figure 9-2 Overview of Ponga Road Upgrade

In addition to those listed above, the key features of the Ponga Road Upgrade section include:

- Roundabout tying into the proposed Ōpāheke N-S FTN Arterial (NoR D4) and Ōpāheke Road Rural Upgrade section
- A bridge over Mangapū Stream
- Extension/upgrade of existing pipe culverts
- Two stormwater wetlands.

9.1.1.2 Specific Features of this section

Stormwater catchments and features are shown on the layout plan for NoR D5 in Appendix 1.

Three sub-catchments are created. Runoff from catchment 1 drains into catchment 2 and discharges at chainage 1440m from Wetland 1 into an existing overland flow path leading to Waipokapū Stream.

Runoff from catchment 3 is collected at a low point (chainage 860 m) and discharges from Wetland 2 into Mangapū Stream.

The proposed transport corridor is designed to follow the existing ground level as far as possible while it crosses a few overland flow paths. The longitudinal slopes range between 0.5% and 3% which allows for enough gradient to drain stormwater runoff from the transport corridor via catchpits into an underground pipe system.

The increased surface runoff generated by the additional impervious surface due to the wider transport corridor, requires flood mitigation to attenuate the post development 100 ARI peak flows to pre-project development peak flow rates.

The transport corridor crosses Mangapū Stream at twin culverts. These culverts are to be upgraded to a new bridge incorporating the new walking and cycling paths.

The total catchment sizes summarized in Table 9-1 includes both the impervious and pervious areas for that catchment.

Table 9-1: Ponga Road Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Management Device type	Attenuation volume provided	Size of wetland permanent water	Discharge point location
1	chainage 1000-1200 (low point at chainage 1060)	4 800 m²	Wetland 1 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall events	603 m³	268 m³	Overland flow path towards Ōtūwairoa Stream at 94 Ponga Road, Drury
2	chainage 1200-1660 (low point at chainage 1440)	11 040 m²				
3	chainage 1660-2040 (low point at chainage 1860)	9 120 m²	Wetland 2 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall events	185 m³	154 m³	Mangapū Stream at 215 Ponga Road, Drury

The existing cross drainage for this transport corridor consists of three culvert crossings. A potential set of cross drainage structures used to assess the potential flooding effects are summarized in Table 9-2. The type and size of cross drainage structures are not fixed and will continue to be assessed through subsequent consenting and design phases.

Table 9-2: Ponga Road Upgrade cross drainage characteristics

Chainage	Upstream catchment (ha)	Existing Cross drainage	Modelled Cross drainage	Modelled Culvert Invert Levels / Bridge (RL)
chainage 1440	3.6	300mm dia. culvert	300mm dia. culvert	25.3m upstream, 22.9m downstream (ground level taken)
chainage 1820	15	900mm dia. culvert (unknown at time of modelling).	600mm dia. culvert	26.3m upstream, 24.6m downstream (ground level taken)
chainage 1940	642	Twin 2000mm dia. culverts	Construct new bridge	Bridge soffit level RL 28.6

9.1.2 Ōpāheke Road Rural Upgrade Section

9.1.2.1 Section Overview

It is proposed to widen, and realign a portion of, the existing road within the Ōpāheke Road Rural Upgrade section to a 24m urban arterial. The Ōpāheke Road Rural Upgrade section extends 1.6km from the extent of the FUZ in the north to Ponga Road in the south. An overview of the concept design is provided in Figure 9-3.

Figure 9-3 Overview of Ōpāheke Road Rural Upgrade

The key features of the Ōpāheke Road Rural Upgrade section include:

- Roundabouts at Bellfield Estate and Ōpāheke N-S FTN Arterial / Ponga Road
- Realignment of a section of Ōpāheke Road and grade separation of the NIMT to avoid the Waikato 1 watermain and Ōpāheke Sports Fields and to allow the bridge to be constructed offline
- New road connection to Walker Road (and closure of a section of the existing Ōpāheke Road – replaced by the new NIMT bridge)
- Two walking and cycling bridges adjoining each side of the existing Ōtūwairoa Stream road bridge
- Two stormwater wetlands. One is an extension of an existing wetland located within Ōpāheke Reserve.

Stormwater related works include one existing culvert crossing requiring extension to accommodate the road widening, one new culvert crossing under Walker Road off Ōpāheke Road, two new wetlands and realignment/shaping of an existing overland flow path, and two new active mode bridges each side of the existing Ōtūwairoa Stream Bridge. A retaining wall is proposed for the abutment of the north western bridge abutment to minimise encroachment onto the banks of Ōtūwairoa Stream. A new grade separated bridge is proposed over the existing NIMT rail line.

9.1.2.2 Specific Features of this section

Stormwater catchments and features are shown on the layout plan for NoR D5 in Appendix 1.

Three sub-catchments are created along the transport corridor. It is proposed that the runoff from catchment 1 discharges into Wetland 1 while catchment 3 is diverted to join catchment 2 and discharge into Wetland 2. The wetlands will discharge either directly or indirectly to the Ōtūwairoa Stream.

The proposed transport corridor is designed to follow the existing ground level as far as possible while it crosses Ōtūwairoa Stream and a few overland flow paths. The longitudinal slopes range between 0.5% and 5.8% which allows for enough gradient to drain stormwater runoff from the transport corridor via catchpits into an underground pipe system.

The increased surface runoff generated by the additional impervious surface due to the wider transport corridor, requires flood mitigation to discharge at the 100 year ARI pre-project development peak flow rates into a nearby overland flow path.

The total catchment sizes summarized in Table 9-3 includes both the impervious and pervious areas for that catchment.

Table 9-3: Ōpāheke Road Rural Upgrade catchment characteristics

Road Catchment	Catchment Chainages	Total Catchment size	SW Manage-ment Device type	Attenua-tion volume provided	Size of wetland permanent water	Discharge point location
1	chainage 1560-2360 (low point at chainage 2060)	19 200 m²	Wetland 1 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall event	405 m³	324 m³	Ōtūwairoa Stream at 156 Ōpāheke Road, Drury
2	chainage 2360-3040 (low point at chainage 2540)	16 320 m²	Wetland 2 for quality treatment, retention and detention, and flood mitigation for the 10 and 100 year ARI rainfall event	485 m³	308 m³	Overland flow path at 202 Ōpāheke Road, Drury
3	chainage 3040-3120 (low point at chainage 3120)	1 920 m²				

A potential set of cross drainage structures for this transport corridor used to assess the potential flooding effects and are summarized in Table 9-4. The type and size of cross drainage structures are not fixed and will continue to be assessed through subsequent consenting and design phases.

Table 9-4: Ōpāheke Road Rural Upgrade cross drainage characteristics

Chainage	Upstream catchment (ha)	Existing Cross drainage	Existing Bridge Levels (RL)	Modelled Cross drainage	Modelled Bridge Levels (RL)
chainage 1950	2 587	Ōtūwairoa Stream Bridge structure, 22m long	Bridge soffit level at 11.64m	Keep existing Ōtūwairoa Stream Bridge and add active mode bridges, single-span, 25m long on either side of the existing bridge.	Bridge soffit level at 11.64m. New bridges set at same level as existing bridge
chainage 2600	15	300mm dia. culvert	Not modelled	300mm dia. culvert	Not modelled

9.1.3 Ōpāheke Road Urban Upgrade Section

9.1.3.1 Section Overview

While the overall plan for the urban area of Ōpāheke Road is to upgrade the walking and cycling facilities from Ōpāheke Road Rural Upgrade in the south to Great South Road, Papakura in the north, only the areas affecting land outside the existing road reserve are proposed to be designated and assessed as part of this assessment. The Ōpāheke Road Urban Upgrade section of NoR D5 includes the regrading of nine driveways along Ōpāheke Road and the upgrade of the Ōpāheke Road / Settlement Road intersection to a roundabout. An overview of the proposed designation areas is provided in Figure 9-4.

The key features of the Ōpāheke Road Urban Upgrade section include:

- Upgrade of the Ōpāheke Road / Settlement Road intersection to a roundabout to provide for separated walking and cycling facilities, including crossing facilities
- Re-grade of nine driveways.

Figure 9-4: Overview of Ōpāheke Road Urban Upgrade

9.1.3.2 Specific Features of this section

It is estimated that the upgrade of the intersection at Ōpāheke Road and Settlement Road increases the existing impervious area from 2,884 m² to 3,605 m² due to the addition of the new cycle and pedestrian pathways on both sides of the corridor. Stormwater management, such as a raingarden, is proposed on the south eastern corner of the roundabout to attenuate and treat the surface runoff.

Improved inlets are proposed north of the intersection to allow for overland flow to cross Settlement Road and not to increase the existing ponding and flood levels on the northern side of the road.

9.2 Existing and Likely Future Environment

9.2.1 Ponga Road Upgrade section

The existing land use along Ponga Road is rural and zoned FUZ. The Auckland Council Drury-Ōpāheke Structure plan shows the future urban zoning will be a mix of Light Industry/Business, Mixed Housing Urban and Mixed Housing Suburban.

The road crosses a few overland flow paths and Mangapū Stream by means of a major culvert crossing. Flood prone areas exist along the road and the flood plain at Mangapū Stream overtops the road.

Earthworks for development within the FUZ upstream will change catchment hydrology, the terrain and building and property types that are potentially exposed to flooding along most of the corridor. Specific issues could include development of land upstream of the raised corridor around chainage 1900m. The assessment has therefore considered specific effects on existing properties and more generally considered effects on potential future development. It is expected that coordination and integration of the corridor design with FUZ development will be required to confirm and address potential future effects.

9.2.2 Ōpāheke Road Rural Upgrade section

The existing land use along the Ōpāheke Road Rural Upgrade corridor is rural and open space.

Under the AUPOIP, the land is zoned FUZ, Open Space – Conservation Zone, Open Space – Informal Recreation Zone, Open Space – Sports and Active Recreation Zone, Business – Neighbourhood Centre Zone and Residential –Mixed Housing Urban and Suburban. The Auckland Council Drury-Ōpāheke Structure plan indicates that the FUZ will most likely be zoned for Light Industry/Business and Mixed Housing Suburban.

Live zone precincts include the Ōpāheke 1 (Bellfield Estate) - a Special Housing Area within the Drury package area east of Ōpāheke Road. Bellfield Estate is expected to contain over 500 dwellings across 22 hectares. Earthworks have started on Stage 1 on Ōpāheke Road.

A few overland flow paths cross the road by means of culverts while Ōtūwairoa Stream crosses the road through a bridge structure. Flood prone areas exist along the transport corridor with a wide flood plain at Ōtūwairoa Stream. The flood plain overtops the existing bridge and there is flooding of properties upstream and downstream of the bridge crossing.

9.2.3 Ōpāheke Road Urban Upgrade section

The existing land use surrounding the Ōpāheke Road Urban Upgrade section is largely established low to medium density residential. Papakura Cemetery is located at the intersection of Ōpāheke Road and Settlement Road.

Under the AUPOIP, the land is zoned Residential – Mixed Housing Suburban, Residential – Mixed Housing Urban, Residential – Terraced Housing and Apartment Buildings and Special Purpose – Cemetery.

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

9.3.1 Ponga Road Upgrade section

This section of the report assesses the impact from construction and operation due to the flood extents and changes in water levels caused by the upgraded transport corridor. A 2D flood model for the Ōtūwairoa Stream catchment has generated the pre- and post-project development scenarios for the 10 year and 100 year ARI rainfall events. This assessment of effects refers to the flood model results and considers the flooding extents at the existing culvert crossings and areas where the new road embankment encroaches existing flood plains. Table 9-5 summarizes the pre-project development and post-project development flood levels at key crossings.

9.3.1.1 Positive Effects

The Ponga Road Upgrade requires new crossings of Mangapū Stream. It is proposed to change the twin existing 2000 dia. culverts to a bridge to accommodate new design levels required to tie into the proposed Mill Road and prevent floods overtopping the road.

The existing road level at Mangapū Stream crossing is 24.71 m and the 100 year ARI pre-project development flood level is 25.71 m. The current road will flood at a depth of 1m at chainage 1940 and extend to about 130m wide. With the change in land use to urban in the future it can potentially increase the flooding effects at Ponga Road. The proposed bridge is at RL 30.75m with a span of 35m.

Table 9-5: Ponga Road Upgrade existing and modelled flood levels at crossings

Chainage	Existing Cross drainage	Existing flood level (MPD + CC) (RL)	Modelled Cross drainage	Modelled Bridge Levels (RL)	Future flood level (MPD + CC) (RL)
chainage 1440	300mm dia. culvert existing road level RL 24.42	100 year ARI rainfall event: 24.59m upstream, 22.4m downstream	600mm dia. culvert Modelled road level RL 25.26		100 year ARI rainfall event: 25.28m upstream, 22.4m downstream
chainage 1820	300mm dia. culvert existing road level RL 26.21	100 year ARI rainfall event: 26.19m upstream	600mm dia. culvert Modelled road level RL 29.55		100 year ARI rainfall event: 27.33m upstream
chainage 1940	Twin 2000mm dia. culverts Existing road level RL 24.71	100 year ARI rainfall event: 26.56m upstream, 25.48m down-stream	Mangapū Stream Bridge structure, single span, 35m long Road CL 30.75	Modelled bridge soffit level RL 28.6 at chainage 1940	100 year ARI rainfall event: 27.09m upstream, 25.84m downstream

9.3.1.2 Assessment of Construction Effects

A bridge is proposed over Mangapū Stream. Other proposed construction works include two existing culvert crossings which require extension to accommodate the road widening and two wetlands. Wetland 1 is located near chainage 1550 outside a flood plain and major overland flow path. Wetland 2 is located near chainage 1750 and is on the edge of the flood plain.

The main construction phase risks are associated with the new bridge over the Mangapū Stream with road levels reducing the amount of road overtopping and new abutments directing that flow toward the existing culverts / potential bridge. The existing twin 2000 dia. culverts may provide a ready-made diversion for the bridge construction works.

A site compound is proposed adjacent to Wetland 1 at chainage 1600 is not within a flood plain or major overland flow path. Other construction yards and stockpile sites are also proposed along the transport corridor. Proposed locations for these are outside flood plains and major overland flow paths and therefore do not present increased flood hazard risks.

9.3.1.3 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Mangapū Stream Bridge

The bridge can be constructed from the transport corridor but will require abutments to be within the flood plain. The abutments may be able to be constructed by maintaining flow through the existing culverts and isolating the abutments from the flow. Further consideration of the required temporary works including staging to avoid exacerbating the potential flooding during construction is required at detailed design.

Culverts

The 300 mm dia. culvert located at chainage 1440 has a relatively minor upstream catchment with minimal flows. Temporary damming without the need for over pumping will be sufficient to provide for a dry working area during the summer earthworks season.

The 300 mm dia. culvert located at chainage 1800 has a relatively minor upstream catchment with minimal flows, and the majority of the catchment draining towards the larger adjacent culvert. Temporary damming and over-pumping will be sufficient to provide a dry working area during the summer earthworks season.

All culverts should be extended prior to commencement of bulk earthworks to allow for the passage of clean water across the site.

Wetlands

The two new wetlands proposed will be located near chainage 1550 and chainage 1750. Localised flow diversion and bunding may be required to ensure dry construction works for the wetlands and their associated outlets.

Mitigation

Flood hazards for the construction phase should be addressed in a CEMP. Key issues to consider are;

- siting construction yards and stockpiles outside the flood plain
- minimising the physical obstruction to flood flows at the existing 2000 dia. culverts from temporary works
- staging and programming to carry out work when there is less risk of high flow events, and
- methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

It is recommended that a condition to the NoR include a requirement for the CEMP to consider flood hazard.

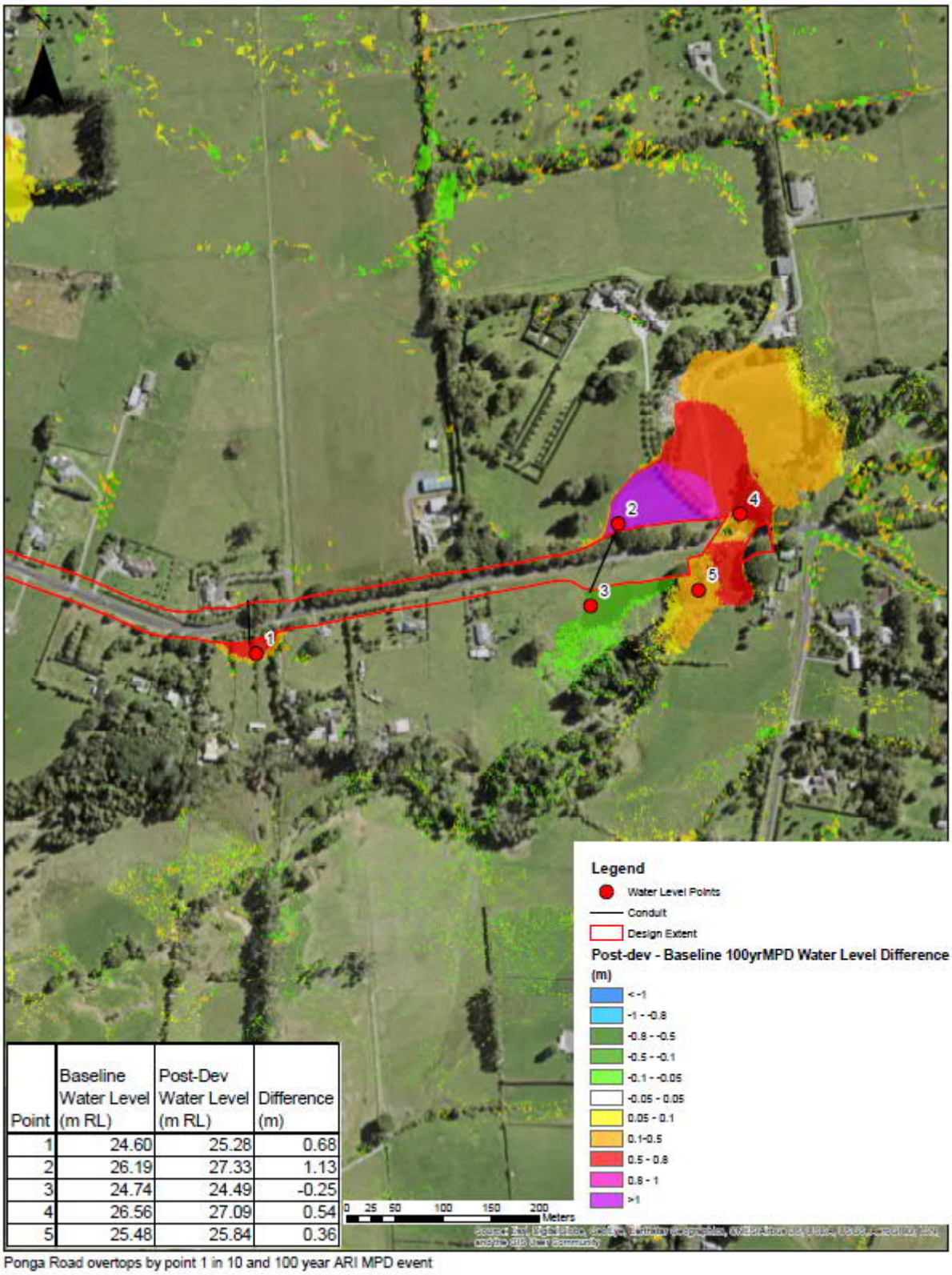
9.3.1.4 Assessment of Operational Effects

This assessment of effects refers to the pre-project development and post-project development flood model results and considers the flooding extents at existing culvert crossings and other significant areas where the new road embankment encroaches existing flood plains. The assessment also considers the extents of flooding on existing properties due to the upgraded transport corridor.

Ponga Road currently crosses Mangapū Stream over two 2000 dia. culverts - with flood flows overtopping the road. The height of the road above the culverts is small with limited upstream ponding before the overtopping would occur. Ponga Road is expected to be raised in this location to allow for tying into the Mill Road vertical alignment immediately to the east. A bridge is needed to allow additional flow under Ponga Road (and prevent floods overtopping the road) and therefore minimise increases to upstream flood levels. There are no existing houses within the flood plain upstream of Ponga Road. The access to two properties at 198 Ponga Road is through the existing flood plain immediately north of the existing twin 2000 dia. culverts and changes in water levels and flow patterns could affect the flood hazard.

The main span of the proposed bridge and upstream abutment geometry will need to be set to minimise increases in flood levels, velocity and flood hazards in the area.

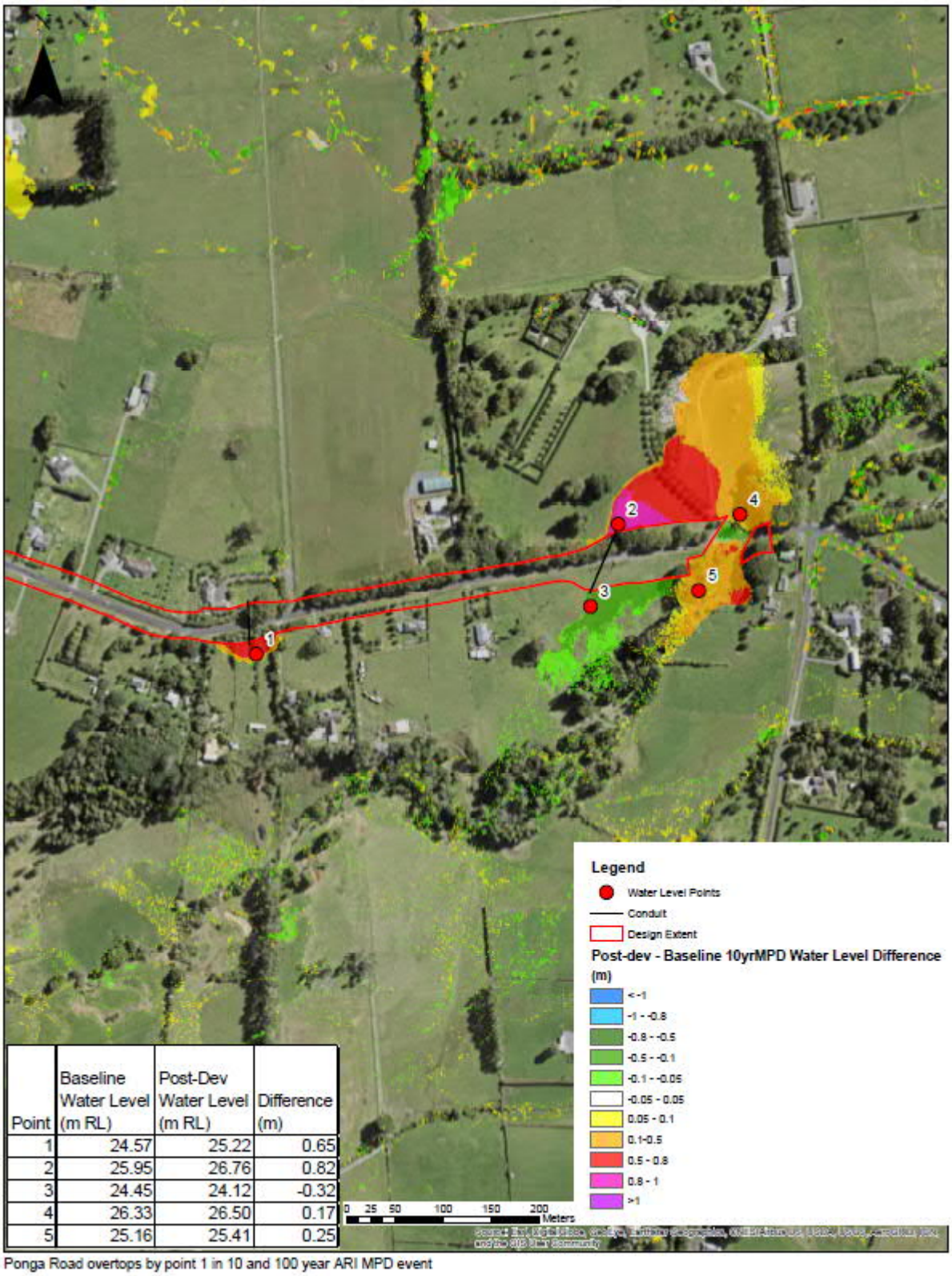
A bridge was modelled with a single span of 35 m and soffit level at 26.8 m. The results for the 100 year ARI scenario indicate that the water level upstream of the bridge increases by 0.57m at the inlet upstream and 0.36m at the outlet downstream (refer to points 4 and 5 in Figure 9-5). The results for the 10 year ARI scenario indicate that the water level upstream of the bridge increases by 0.17 m at the inlet upstream and 0.25 m at the outlet downstream (refer to points 4 and 5 in Figure 9-6.) However, the change in flood levels is less than 50mm within 150m upstream and within 80m downstream. The increase in water levels appears to be due to the diversion of flow previously overtopping the road and water building up at the culvert to the west. The culvert capacity, bridge capacity and abutment geometry needs to be optimised / increased.



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	24.60	25.28	0.68
2	26.19	27.33	1.13
3	24.74	24.49	-0.25
4	26.56	27.09	0.54
5	25.48	25.84	0.36

Ponga Road overtops by point 1 in 10 and 100 year ARI MPD event

Figure 9-5: 100 Year flood difference map for post- minus pre-project development at Ponga Road culvert and bridge crossings



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	24.57	25.22	0.65
2	25.95	26.76	0.82
3	24.45	24.12	-0.32
4	26.33	26.50	0.17
5	25.16	25.41	0.25

Ponga Road overtops by point 1 in 10 and 100 year ARI MPD event

Figure 9-6: 10 Year flood difference map for post- minus pre-project development at Ponga Road culvert and bridge crossings

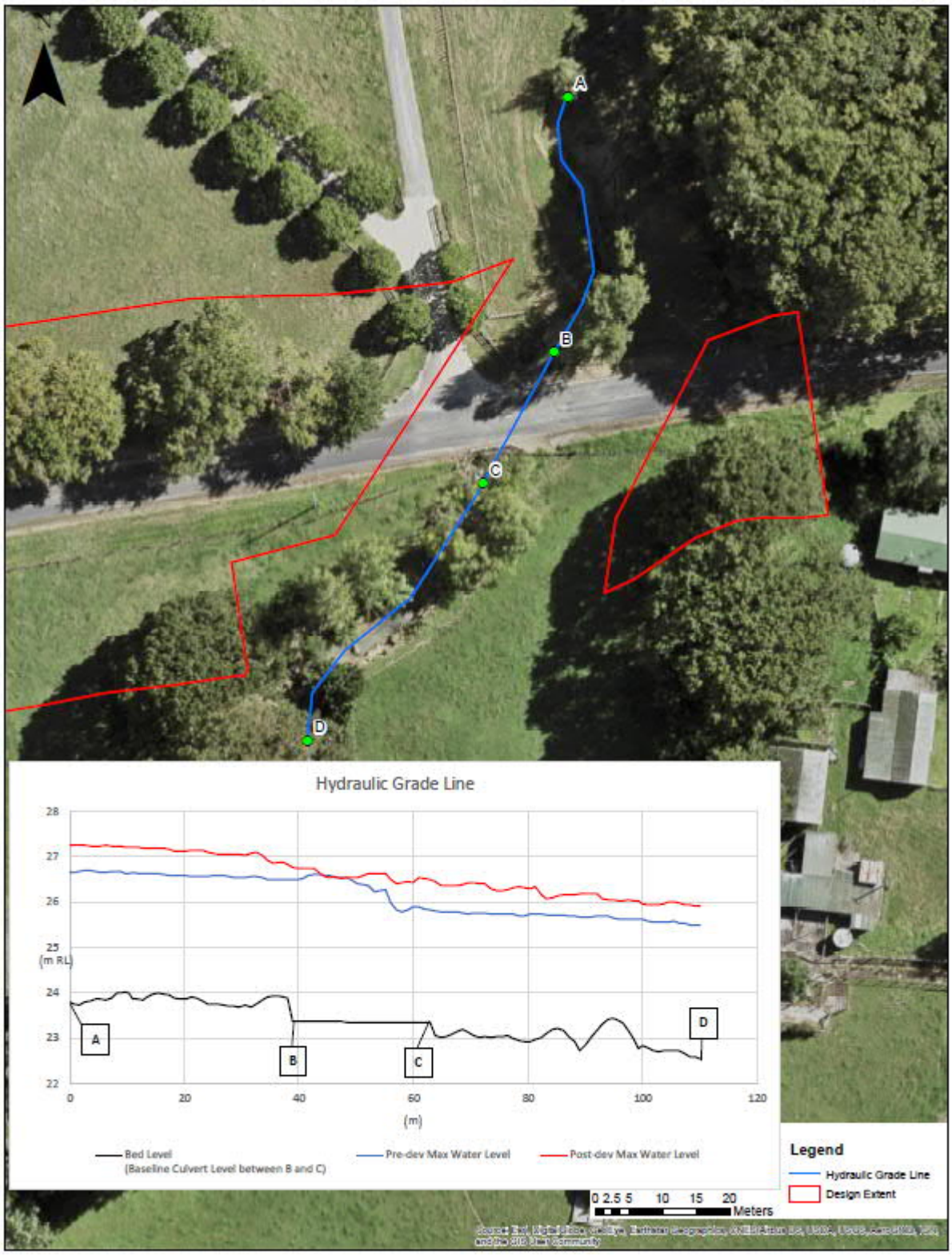


Figure 9-7: Hydraulic grade line, 100 year ARI event at Ponga Road and Mangapū Stream crossing

9.3.1.5 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The potential bridge at Mangapū Stream will need to have sufficient span and the culvert to the west have capacity to accommodate flows that previously overtopped the road, the abutments set back from the main channel to avoid overly constricting flows and its deck should have appropriate freeboard to the 100 year ARI flood level. Changes to the flood hazard for access for the house at 198 Ponga Road should be considered further at detailed design and a condition is recommended to address this. If required, mitigation would consist of decreasing the depth of flooding by increasing the culvert diameter and optimising the abutment geometry, span and flow capacity of the proposed bridge.

The culvert crossing at chainage 1440 (some 400m further to the west) should potentially be upgraded to allow more flow to pass through and mitigate increased ponding upstream.

9.3.1.6 Summary and Conclusions

There are no significant flood hazard issues associated with the construction phase of the Ponga Road Upgrade. Potential flood hazards associated with the works should be considered in the proposed Construction Management Plan.

The proposed Ponga Road vertical alignment is required to tie in with the proposed Mill Road corridor. Raising the vertical alignment improves flood resilience of the corridor but potentially obstructs flow and a bridge is required to mitigate this effect. The potential bridge span and abutments should be considered further at detailed design with their shape and location optimised within its general location to minimise potential flooding effects. There are no significant flooding issues expected with the proposed culverts or wetlands at Ponga Road.

9.3.2 Ōpāheke Road Rural Upgrade section

This section of the report assesses the impact from construction and operation of the proposed works on flood extents and changes in water levels. A 2D flood model for the Ōtūwairoa Stream catchment has been generated for the pre- and post-project development scenarios for the 10 year and 100 year ARI rainfall events. This assessment of effects refers to the flood model results and considers the flooding extents at the existing bridge over Ōtūwairoa Stream and areas where the new road embankment encroaches significantly on existing flood plains. Table 9-6 summarizes the pre-project development and post-project development flood levels at key crossings.

Table 9-6: Ōpāheke Road Rural Upgrade existing and future flood levels at key crossings

Chainage	Existing Cross drainage	Existing Bridge Levels (RL)	Existing flood level (MPD + CC) (RL)	Modelled Cross drainage	Modelled Bridge Levels (RL)	Future flood level (MPD + CC) (RL)
chainage 1900	Ōtūwairoa Stream Bridge structure, 22m long	Bridge soffit level at 11.64m	10 year ARI rainfall event:11.54m upstream, 10.78m downstream	Existing Ōtūwairoa Stream Bridge structure with two additional active mode bridges (single-span, 25m long) on either side of the existing bridge.	Bridge soffit level remains at 11.64m with the new active mode bridges on either side at the same level	10 year ARI rainfall event:11.64m upstream, 10.79m downstream
			100 year ARI rainfall event: 12.01m upstream, 11.09m downstream			100 year ARI rainfall event: 12.15m upstream, 11.11m downstream

9.3.2.1 Assessment of Construction Effects

The new walking and cycling path bridges can likely be constructed from the existing road and bridge. The retaining wall construction for the north east abutment will be close to the existing stream channel and may require sheet piling to separate construction from the main flow channel. Where sheet piling is required to separate woks from the channel, flood flows will be constricted and the potential for flooding effects will be greater than the existing bridge for the period of the works.

The new bridge over the rail line is close to several existing overland flow paths.

A site compound is proposed adjacent to Wetland 2, at chainage 2500 partly within a flood plain and across an existing overland flow path.

There could be adverse effects associated with diversion of flows during construction of culverts if this is not appropriately sequenced.

9.3.2.2 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Bridges

The two active mode bridges are two separate single span bridges constructed adjacent to the existing Ōtūwairoa Stream Bridge crossing. The bridges will include spill through abutments with driven piles either side of the stream banks. Works will need to be isolated from the main stream channel so that flood flows can continue to pass unimpeded. Flood hazard effects should be considered further through the CEMP – specifically the flow constriction effect of sheet piling or temporary platforms at the bridge abutments.

The overland flow path obstructed by the eastern approach for the new rail overbridge will need to be diverted to avoid flooding of the working area and adjacent site compound.

Culverts

The existing culvert requiring extension is located at chainage 2600 and caters for a minor catchment of adjacent properties, on the south side of Ōpāheke Road. Temporary damming will be suitable upstream for the short duration of construction expected for the extension during the dry season, without the need for over pumping.

Wetlands

Wetland 1 is located at chainage 2100 in the Ōpāheke Reserve. It is an extension of the existing Auckland Council Stormwater pond. The wetland is on the edge of the Ōtūwairoa Stream flood plain, with the new outlet discharging into Ōtūwairoa Stream. Minor flow diversions will be required either side of the construction area.

Wetland 2 will be constructed north of Ōpāheke Road chainage 2500, north of an existing ponding area. Staging of the wetland construction and new culvert crossings and diversion drains and extension of the existing crossing will need to consider the potential construction phase flooding effects.

Flood hazards for the construction phase should be addressed in a CEMP. Key issues to consider are:

- siting construction yards and stockpiles outside the flood plain
- minimising the physical obstruction to flood flows under the existing bridge from temporary works
- staging and programming to carry out work when there is less risk of high flow events, and
- methods to reduce the conveyance of materials and plant that is considered necessary to be stored or sited within the flood plain (e.g. actions to take in response to the warning of heavy rainfall events)

9.3.2.3 Assessment of Operational Effects

This assessment of effects refers to the existing (pre-project development) and future (post-project development) flood model results and considers the flooding extents at the existing Ōtūwairoa Stream Bridge and significant areas where the new road embankment encroaches existing flood plains. The following key areas are identified and described in more detail in the sections below:

- Ōtūwairoa Stream Bridge
- Rail overbridge
- Properties upstream of Ōtūwairoa Stream Bridge
- Proposed Stormwater Wetlands

9.3.2.3.1 Ōtūwairoa Stream Bridge

New active mode bridges are proposed on either side of the existing bridge across Ōtūwairoa Stream using single span, 25 m long structures with 900 mm single hollow core girders and spill-through abutments.

The pre-project development flood model results for the 100 year ARI rainfall event at the Ōtūwairoa Stream Bridge are RL 12.01 m upstream and RL 10.81 m downstream (points 1 and 2 in Figure 9-8). The existing bridge deck level is at RL 11.64 m resulting in zero freeboard with the flood overtopping the road for some 240m (mostly to the south-east).For the post project scenario, the flood level immediately upstream of the bridge increases to 12.15m and at 156 Ōpāheke Road increases by 0.11m.

During the 10 year event, the upstream flood level increases from RL 11.54 m to 11.63, which indicates that the 10 year event is very close to overtopping the bridge.

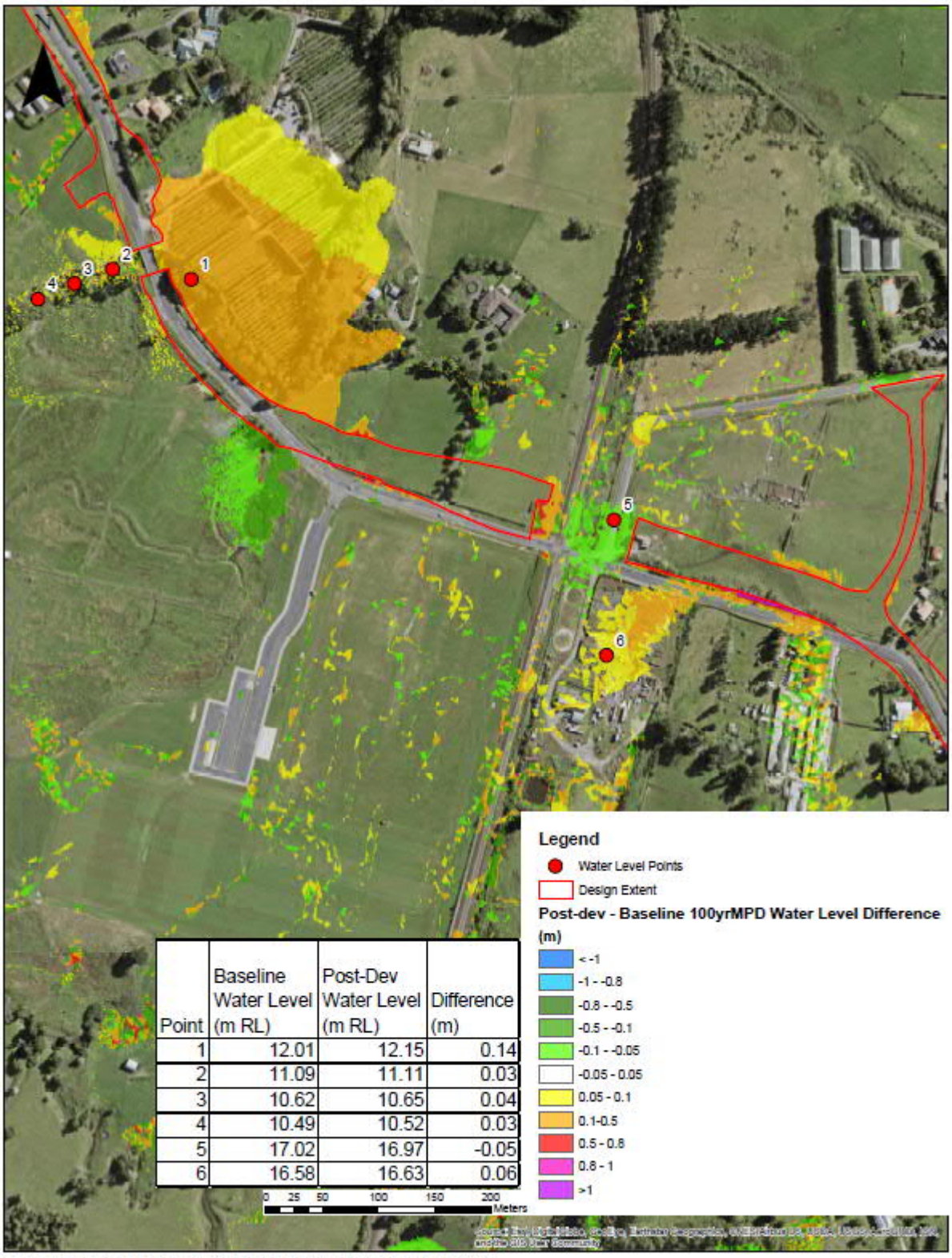
The effect at 156 Ōpāheke Road (refer to property H in Figure 9-11) is discussed in section 9.3.2.3.3.

The existing bridge over the Ōtūwairoa Stream currently overtops - with the proposed pedestrian / cycle bridges set at the same level as the existing bridge to avoid increasing upstream flood levels further. Given this flooding is to continue, it is recommended that a management response is developed to prevent use of the bridges during significant flooding events.

9.3.2.3.2 Rail Overbridge

The proposed rail overbridge is sited to the north of the existing Ōpāheke Road and will obstruct an existing overland flow path to the north of the eastern rail bridge abutment. Provided the existing drain within the existing road reserve is maintained and a new overland flow path past wetland 2 is provided to divert flow around the north side of the approach embankment, the flooding effects should be minor.

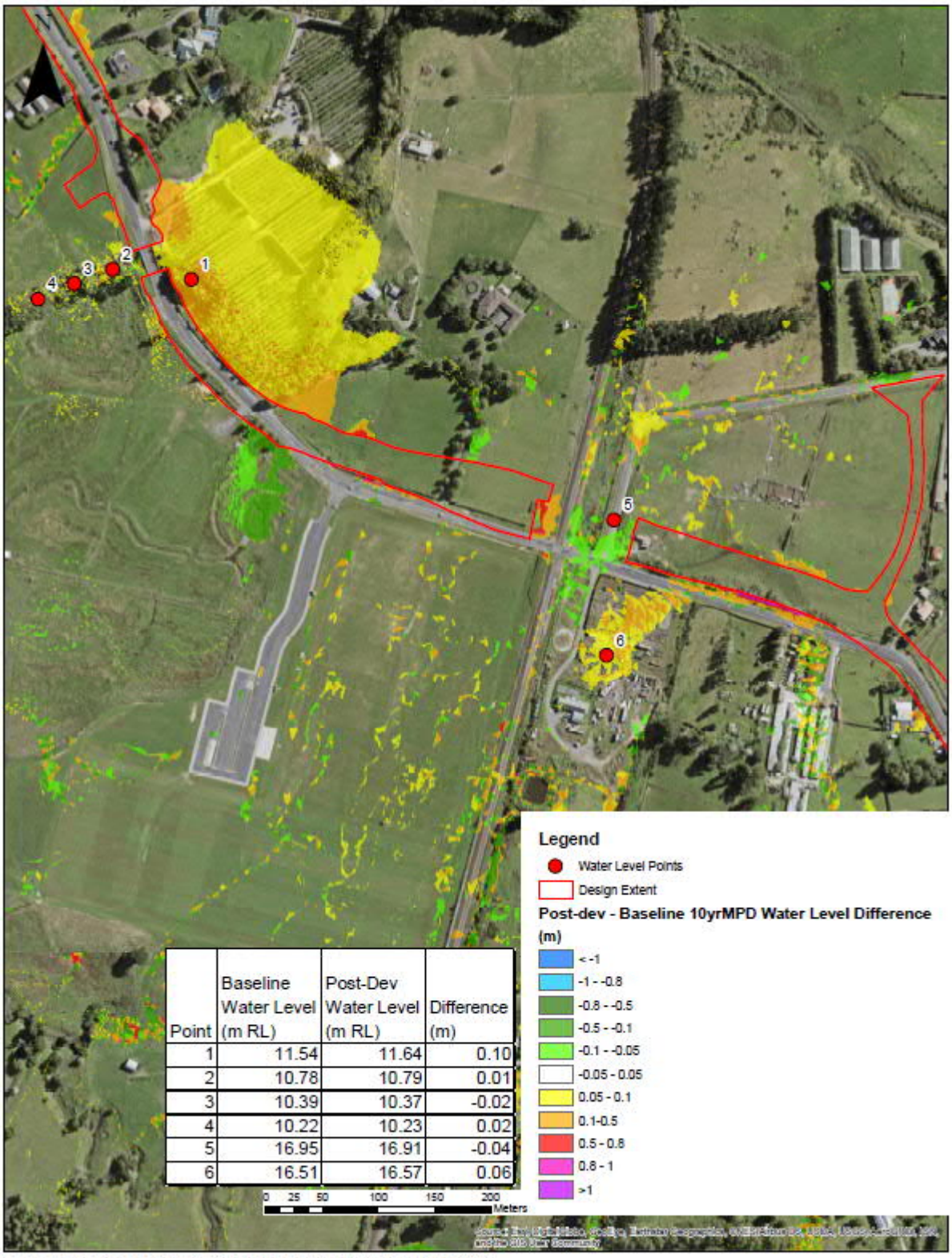
The increase in water levels south of the corridor at point 6 in Figure 9-8, is due to the upgraded corridor obstructing the existing drain running south of the existing road towards the rail line. This can be mitigated by realigning the drain from chainage 2600 to 2150 to run alongside the upgraded corridor and discharging into Ōtūwairoa Stream.



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	12.01	12.15	0.14
2	11.09	11.11	0.03
3	10.62	10.65	0.04
4	10.49	10.52	0.03
5	17.02	16.97	-0.05
6	16.58	16.63	0.06

Road overtops to the south of point 1 in the 10 and 100 year ARI MPD events.
Increased flooding ocurs at point 6 due to blocking off a flow path towards the railway.

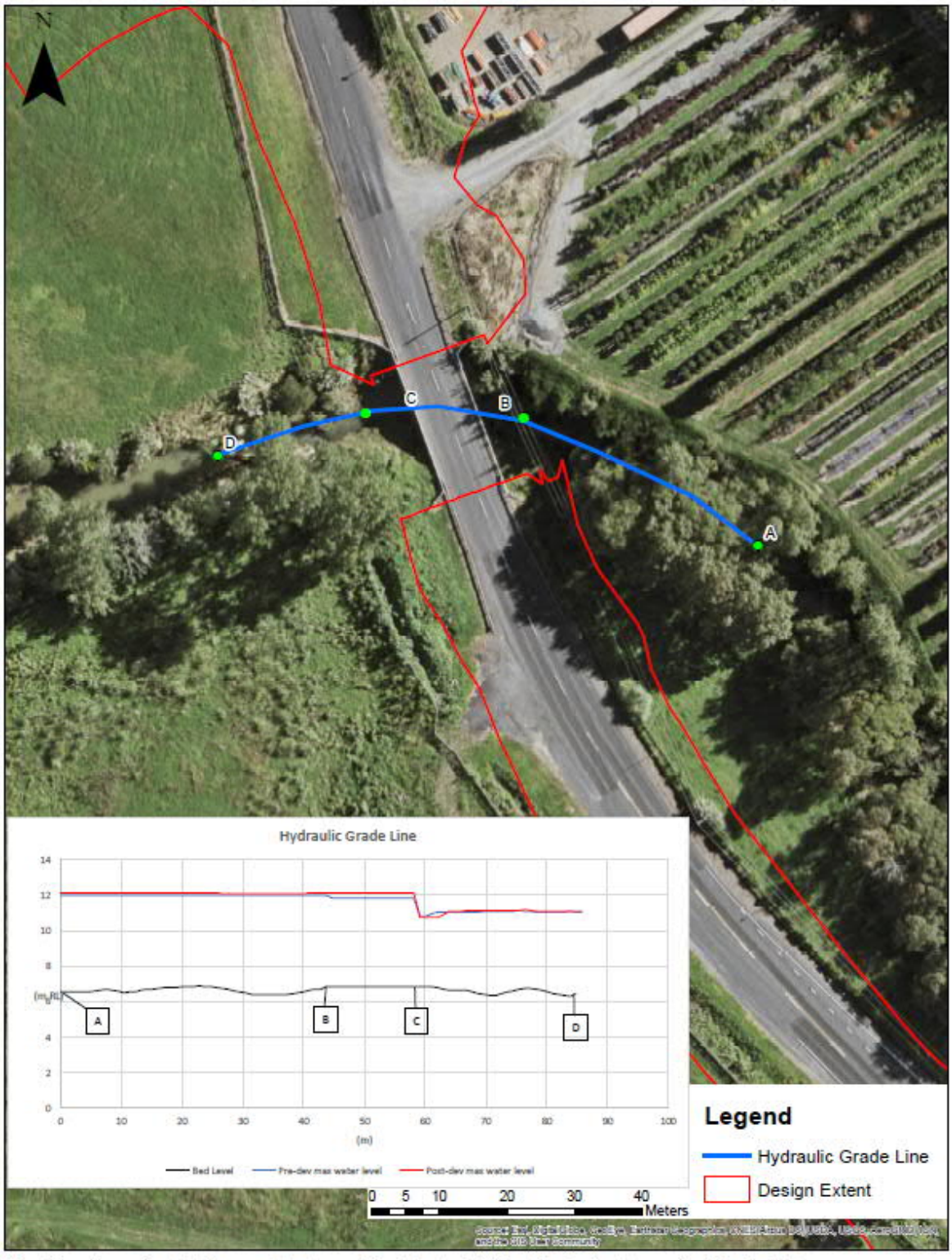
Figure 9-8: 100 Year flood difference map for post- minus pre-project development at Ōpāheke Road and Ōtūwairoa Stream crossing



Point	Baseline Water Level (m RL)	Post-Dev Water Level (m RL)	Difference (m)
1	11.54	11.64	0.10
2	10.78	10.79	0.01
3	10.39	10.37	-0.02
4	10.22	10.23	0.02
5	16.95	16.91	-0.04
6	16.51	16.57	0.06

Road overtops to the south of point 1 in the 10 and 100 year ARI MPD events.
Increased flooding ocurs at point 6 due to blocking off a flow path towards the railway.

Figure 9-9: 10 Year flood difference map for post- minus pre-project development at Ōpāheke Road and Ōtūwairoa Stream crossing



A head loss of approximately 1.2m occurs downstream of the bridge (point C) due to the significant expansion of the floodplain.

Figure 9-10: Hydraulic grade line, 100 year ARI at Ōpāheke Road and Ōtūwairoa Stream crossing

A head loss of approximately 1.2 m occurs at the bridge (point C in Figure 9-10) due to the significant constriction caused by the lack of cross sectional flow area under the bridge.

9.3.2.3.3 Property Assessment

According to the Auckland Council Modelling Specification a freeboard of 500 mm should be added on top of the 100 year ARI MPD flood level for habitable floor levels to have adequate freeboard and safe for use. Buildings floors potentially affected by the flood hazard are counted either as being below the 100 year flood level or within 500 mm of the 100 year flood level. Driveways and parking areas should be kept save from flooding with allowable water depths below 150 mm for cars and 300 mm for trucks.

Flooding areas upstream of Ōtūwairoa Stream crossing and the Ōpāheke Road over rail crossing were identified as a potential risk to increased flooding. Three areas, as shown in Figure 9-11 and Table 9-7 have increased water levels.

The flood modelling has considered the new walking and cycling path bridges by incorporating them in the model at the same level as the existing Ōpāheke Road Bridge. The current road bridge is submerged during a 100 year flood and the new bridges are therefore also within the flood flow. An increase in the upstream flood level of up to 110 mm occurs which will potentially affect several upstream properties (identified as property F, G, H in the table below). Property H is estimated to be affected by an increase in water level of 0.11 m, while Properties G and H are 30mm or less. A site visit identified that the Property H is a two storey dwelling with the lower floor having a basement/bedroom areas. The lower floor was approximately at ground level (of approximately RL 11.7) and would therefore be flooded during the pre project scenario to a depth of 0.7 m.

The flooding at Point 6 on Figure 9-8 (201 Ōpāheke Road) can be managed by maintaining the capacity of the existing roadside drainage system (on the north side of the existing Ōpāheke Road alignment).

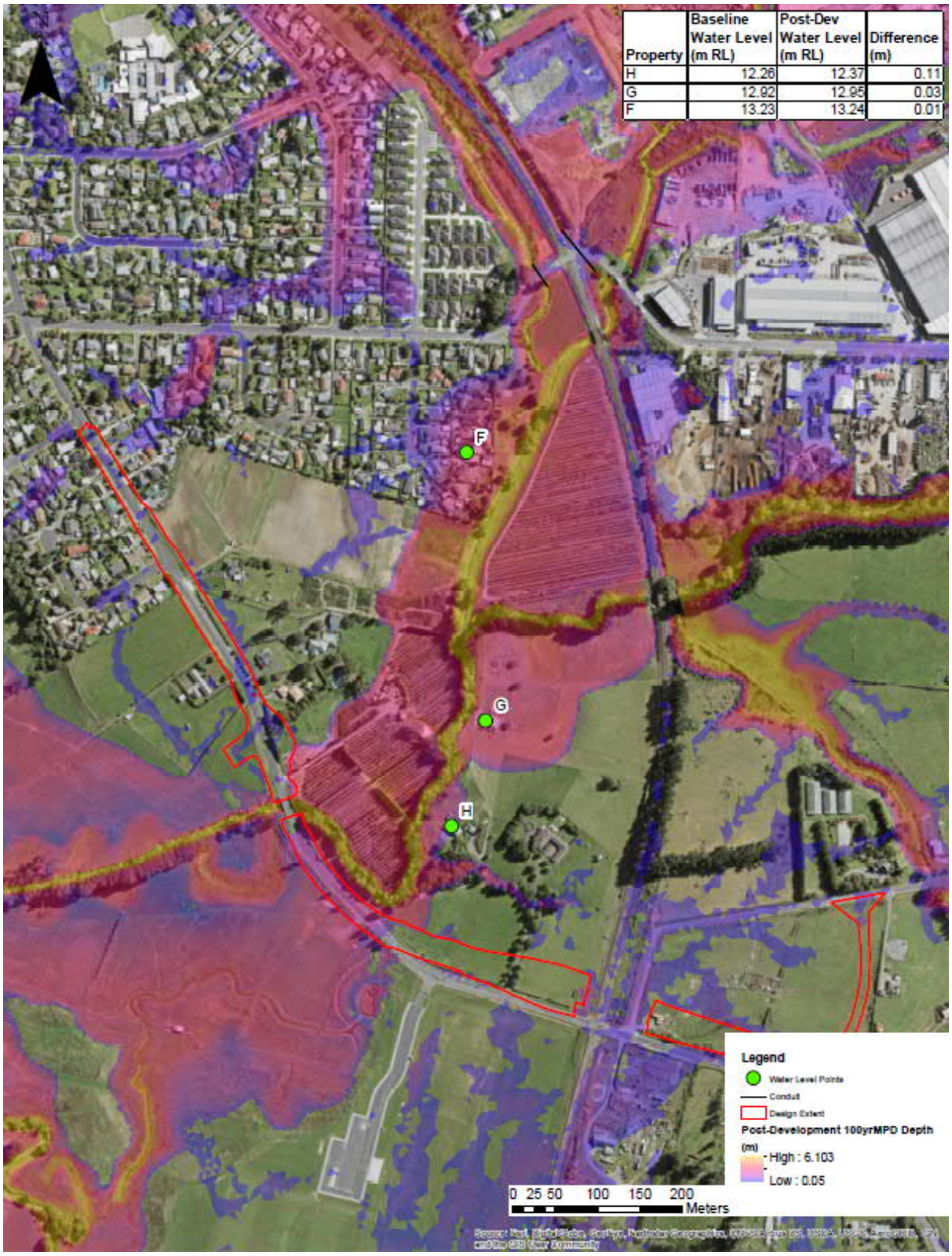


Figure 9-11: Property assessment locations upstream of Ōpāheke Road and Ōtūwairoa Stream crossing

Table 9-7: Properties potentially at risk of flooding along Ōpāheke Road Rural and surrounds

Point on difference map	Property address	Affected area	Water level difference for 100-year post minus pre-project development	100-year flood level (RL)	Comments
Property F	12, 14, 16, 18, 20, 22, 24, 26, 28, 30 Lipton Grove, Papakura	Urban, houses, site levels at RL 11.0 to 13.0	+0.01m	Pre-dev:13.23m Post-dev:13.24	Increase in flood level less than 50mm; minor
Property G	156 Ōpāheke Road, Drury	Building / shed, FUZ, site levels at RL 12.0	+0.03m	Pre-dev:12.92m Post-dev:12.95m	Increase in flood level less than 50mm; minor. Further assessment suggested at detailed design.
Property H	156 Ōpāheke Road, Drury	Building / house, FUZ, site levels at RL 11.5. Lower level floor near ground level.	+0.11m	Pre-dev:12.26m Post-dev:12.37m	Increase in flood level 50mm to 500mm; moderate effect – further assessment required; mitigation required.

9.3.2.3.4 Wetlands

Wetland 1 at chainage 2100 is an extension to an existing wetland within the Ōpāheke Reserve, which is also located within the 100 year ARI flood plain. The wetland location is at the far eastern edge of the flood plain however, outside of the main flow path in the “shadow” of the existing road and with no nearby buildings. It is expected that this will cause no more than minor effects.

Wetland 2, at chainage 2550, is close to an existing overland flow path, but is not expected to obstruct flows to more than a minor extent. A diversion for the flow path obstructed by the eastern approach to the rail overbridge will however be required.

9.3.2.4 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

9.3.2.4.1 Ōtūwairoa Stream Bridge

The proposed two cycle / pedestrian bridges have an effect on flood levels and in particular causes an increase in the depth of flooding of 110mm at Property H. The existing bridge span may need to be increased to reduce the increase in flood level on the upstream dwelling at 156 Ōpāheke Road or the reduction in freeboard otherwise mitigated. This will require further assessment during detailed design.

9.3.2.5 Summary and Conclusions

Works associated with walking and cycling path bridges will need to be isolated and require the main channel to be unobstructed.

Flood hazards during the construction works should be considered in a CEMP.

There is a predicted increase in flood level due to the current level and geometry of the new walking and cycling path bridges over Ōtūwairoa Stream. The loss of freeboard to the property at 156 Ōpāheke road requires mitigation – further assessment is recommended in future design phases. Given flooding over the bridge is to continue, it is recommended that a management response is developed to prevent use of the bridges during significant flooding events.

The rail over bridge geometry is affecting an overland flow path under the eastern abutment. A new diversion drain will be required to divert this flow around the abutment.

9.3.3 Ōpāheke Road Urban Upgrade section

9.3.3.1 Assessment of Construction Effects

Works include reconfiguring drainage to accommodate the new intersection and treating and attenuating runoff within a rain garden near the south eastern corner of the intersection.

There could be adverse effects associated with diversion of flows during construction of the works if this is not appropriately sequenced.

9.3.3.2 Recommended Measures to Avoid, Remedy or Mitigate Construction Effects

Temporary damming or diversion of upstream pipework and overland flow during a dry period will be suitable for the short duration of construction expected.

Flood hazards for the construction phase should be addressed in a CEMP.

9.3.3.3 Assessment of Operational Effects

Modelling has not been carried out at this location due to the small change in impervious area and terrain. The works could disturb the existing overland flow path that crosses Settlement Road from north to south and that then runs overland through residential properties to the south-east. The increase in impervious area increase could increase the overland flow peak rate and exacerbate existing flooding effects downstream.

9.3.3.4 Recommended Measures to Avoid, Remedy or Mitigate Operational Effects

The following mitigation is recommended:

- Surface runoff from the intersection is captured and attenuated so that the 10 and 100 year ARI peak flow rates do not increase
- Improve inletting capacity at existing low spots to capture flow in the pipe system rather than let it run overland.

There is the opportunity for surface runoff from the intersection from chainage 520 to be treated and attenuated in the south east corner of the designation for the new intersection. The discharge could then be connected to the existing 450 mm dia. pipe along King Edward Avenue.

It is recommended that this approach be considered further and confirmed in future design stages.

9.3.3.5 Summary and Conclusions

The overland flow path crossing Settlement Road from north to south may be disturbed. This can be mitigated by improved inlets to capture flow and discharge into the existing pipe network. There is an opportunity for a stormwater management device such as a raingarden for treatment and attenuation at the intersection and connected to an existing pipe along King Edward Avenue.

9.4 Conclusion

9.4.1 Ponga Road Upgrade section

A new bridge is proposed over Mangapū Stream at Ponga Road. The main bed and low flow channel needs to remain unobstructed during construction, with work undertaken from the existing road. The constriction effect of temporary works and flood hazards for the works should be considered in the proposed CEMP. A condition is recommended to require this.

In terms of operational phase effects, the proposed new bridge and approaches over Mangapū Stream will be above the flood plain giving an improved level of service compared to the existing road and reducing the hazard for users. The span and arrangement of the bridge and adjacent culvert will need to be assessed further in future design phases to minimise any effects on access to existing properties upstream.

9.4.2 Ōpāheke Road Rural Upgrade section

The main channel of Ōtūwairoa Stream should remain unobstructed during construction, with work preferably undertaken from the existing bridge/road. Sheet piling may be required to separate the working area from the stream, particularly for the retaining wall at the north-eastern abutment. Flood hazards for the works should be considered in a CEMP.

There is a 140 mm predicted increase (immediately upstream of the bridge) in flood level due to the current level and geometry of the new walking and cycling path bridges over Ōtūwairoa Stream. An increase of 110mm also occurs upstream to the dwelling at 156 Ōpāheke Road which will require mitigation. One option is to increase the span of the overall bridges.

The existing bridge over the Ōtūwairoa Stream overtops with the proposed pedestrian / cycle bridges set at the same level as the existing bridge to avoid increasing upstream flood levels further. A management response is recommended to be developed to manage access and to mitigate the flood hazard.

The rail over bridge geometry is affecting an overland flow path partly under the eastern abutment, with a diversion drain required to mitigate the effects.

9.4.3 Ōpāheke Road Urban Upgrade section

The intersection arrangement will affect an overland flow path to the east. It is recommended to provide stormwater treatment and attenuation to manage the effect of increasing impervious area, intercept the overland flow path and connect this directly back to the pipe system to the east. If levels allow it is recommended to intercept the overland flow path and direct it east along Settlement Road and avoid exacerbating flooding on low lying properties to the south east of the intersection.

9.4.4 Recommendations for NoR D5 conditions

Construction effects

It is recommended that a CEMP shall be developed prior to construction. The CEMP shall consider and mitigate potential adverse flood hazard effects. The flood hazard effects shall be assessed by an experienced Stormwater Engineer and shall consider the effects of temporary works, earthworks, storage of materials and temporary diversion and drainage on flow paths, flow depth and velocity.

Operational effects

It is recommended that detailed design should demonstrate that the Mangapū Stream (Symonds Stream) located at NZTM 1775480, 5893662 is crossed by a bridge.

It is recommended that during detailed design, that flood modelling of the pre project and post project 100 year ARI flood levels (both for MPD land use and including climate change) is carried out and measures implemented to achieve the following outcomes:

1. 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)
2. 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)
3. 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
4. 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)
5. that there is no more than a 10% average increase of flood hazard (defined as flow depth times velocity) for main access to authorised habitable dwellings.

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

10 Conclusion

There are potential flooding effects which can be appropriately managed and mitigated by the conditions proposed in this report, and with these conditions in place, the following conclusions for this Assessment of Flooding Effects are provided.

NoR D1: Alterations to NZ Transport Agency designation 6706 – State Highway 22 (SH22) Upgrade

There is likely to be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridge, however it is expected that the works can be carried out in a way that will appropriately manage this risk.

The overall effect of the upgrade on operational phase flood hazards is positive due to the greater conveyance capacity of the new Ngakoroa Stream Bridge. This results in much improved freeboard to the bridge (with benefits to the safe passage of flow safety of those using the bridge) and reduced flood levels upstream with improved safety for the public and properties.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Setting the levels of the new bridge over the Ngakoroa Stream to be flood resilient
- Design of the corridor levels on SH22 at chainage 2100 to manage the overflow from the Ngakoroa Reserve
- If required, providing flood attenuation for wetland 2 to manage flooding effects downstream

NoR D2: Jesmond to Waihoehoe West FTN Upgrade – Jesmond Road Section

Potential construction phase flooding effects can be managed. With the proposed CEMP taking account of flooding, potential flooding effects are expected to be minor.

Overall, the Jesmond Road FTN Upgrade could have some effect on operational phase flood levels at the sag points where overland flow crosses the transport corridor. With careful design of road levels and upsizing of culverts, flood levels can be managed to be no worse than they currently are. Construction of a diversion drain at 119, 125 and 131 Jesmond Road will direct/formalise overland flow away from the sag at the corridor around nearby buildings and wetland 2 to the open stream channel north of 131 Jesmond Road.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Not worsening freeboard by more than 10%, or mitigating a reduction in freeboard, to existing authorised habitable floor levels
- Not worsening flood levels for existing authorised habitable floors that are already subject to flooding

- Providing an overland flow path from the berm outside 119 Jesmond Road, drain ponding on 125/131 Jesmond Road, around the proposed wetland at 131 Jesmond Road and discharge to the stream channel north of 131 Jesmond Road
- The design of the corridor levels and culverts on Jesmond Road to manage changes to upstream flooding
- If required, providing flood attenuation for wetlands 1 and 2 to manage existing flooding effects downstream

NoR D2: Jesmond to Waihoehoe West FTN Upgrade – Bremner Road Section

Potential construction phase flooding effects can be managed through the proposed CEMP. At Ngakoroa and Hingaia Streams there may be some increase to flood hazards during the construction phase, primarily due to the temporary staging platforms required for constructing the new bridges. However, it is expected that the works can be carried out in a way that will appropriately manage the risk.

The overall effect of the upgrade on operational phase flood hazards in the Hingaia Stream is positive due to the greater conveyance capacity of the new Hingaia Stream Bridge. This results in much improved freeboard to the bridge (with benefits to the safe passage of flow safety of those using the bridge) and reduced flood levels upstream with improved safety for the public and properties.

Using a culvert at the proposed crossing at chainage 600 on Bremner Road will cause an increase in flood levels upstream of the proposed transport corridor. The area of ponding upstream of the culvert would be relatively large and although the culvert is large, there is a risk of partial blockage which would increase flood hazards when future urban development is considered. A bridge is proposed instead to mitigate the flooding upstream of the crossing.

The flood effects at Ngakoroa Steam show an increase in flood levels upstream and due to the constraint of the overhead high voltage Transpower lines, the proposed bridge cannot achieve adequate freeboard and will continue to obstruct the flood flow. Ongoing coordination and integration with Waka Kotahi is required to set bridge levels to suit both the State Highway 1 Papakura to Drury South widening project and the Bremner Road FTN upgrade project.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Setting the levels of the new bridges at chainage 600m on Bremner Road and over the Hingaia Stream to be flood resilient
- Setting the levels and geometry of the new bridge over the Ngakoroa Stream to be flood resilient and manage flood hazard
- That a bridge be used for the crossing at chainage 600m on Bremner Road FTN
- That the existing Norrie Road Bridge is removed prior to the new bridge over the Hingaia Stream being opened
- That a flood hazard management approach continues to be used for flooding of the Bremner Road/Firth St intersection.

NoR D2: Jesmond to Waihoehoe West FTN Upgrade – Waihoehoe Road West Section

There are no significant flood hazard issues associated with the construction or operational phase of the Waihoehoe Road West upgrade. Flood hazards during the construction works should be considered in the proposed CEMP.

No specific measures are recommended for flood hazard mitigation during the operational phase.

Integration of the discharge points with adjoining development plans is needed.

NoR D3: Waihoehoe Road East Upgrade

There are no significant flood hazard issues associated with the construction phase of the Waihoehoe Road East upgrade. Flood hazards during construction works should be considered in the proposed CEMP.

No specific measures are recommended for flood hazard mitigation during the operational phase.

Integration of the discharge points with adjoining development plans is needed.

NoR D4: Ōpāheke N-S FTN Arterial

Overall, the flooding effects arising from the proposed bridges and wetlands in terms of both the construction and operation phases can be appropriately mitigated, and with the measures proposed the effects are expected to be no more than minor.

There are several locations along the route where diversion drains are required on the upstream side of the embankment to prevent increases in flood levels, prevent flood prone areas being formed and mitigate the risk of culvert blockage.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Setting the levels of the new bridges over the Waipokapū and Waihoehoe Streams to be flood resilient
- Not worsening freeboard by more than 10%, or mitigating a reduction in freeboard, to existing authorised habitable floor levels
- Not worsening flood levels for existing authorised habitable floors that are already subject to flooding
- 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
- Providing sufficient culvert capacity or setting transport corridor design levels or providing an overland flow path to avoid creating flood prone areas - particularly at chainages 1400, 1900m, 2200m, 2500 to 2700m and 3000 to 3700m
- Incorporating methods to minimise the risk of culvert blockage – particularly at chainage 1400m and 2200m
- Diversion of flood flows and overland flows around stormwater wetlands

- Managing the potential for wetlands 3 and 4 to be overtopped by flood flows and be subject to erosion
- If required, providing flood attenuation for corridor runoff within wetlands 1, 2, 3 and 4
- That the proposed crossings of the Waipokapū (formerly Hays) and Waihoehoe Streams should be bridges
- Coordination occurs with Auckland Council and adjacent property owners/developers to address flood hazard issues through the corridor design and upstream development design processes.

NoR D5: Ponga Road and Ōpāheke Road Upgrade – Ponga Road Section

There are no significant flood hazard issues associated with the construction phase of the Ponga Road upgrade. Flood hazards during construction works should be considered in the proposed CEMP.

The height of Ponga Road at the new Mangapū Stream Bridge could cause flood waters upstream of the crossing to increase in depth and adversely affect access to a nearby property. The shape of abutments and span of the bridge should be shaped and optimised (within its general location) to minimise increases in flood levels approaching the bridge and changes to flood hazards.

The vertical alignment of Ponga Road over the Mangapū Stream increases to tie in with Mill Road. This will increase the resilience of the road to flooding as flows currently overtopping the road will be diverted under the new bridge.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Setting the levels of the new bridge over the Mangapū Stream to be flood resilient
- Setting the span and arrangement of the Mangapū Stream Bridge to manage increases to upstream flood levels
- Managing effects on access due to flood hazard
- If required, providing flood attenuation for corridor runoff within Ponga Road wetlands 1 and 2
- That the proposed crossing of the Mangapū Stream should be a bridge

NoR D5: Ponga Road and Ōpāheke Road Upgrade – Ōpāheke Road Rural Section

It is important to maintain conveyance capacity of Ōtūwairoa Stream during construction of the shared path bridges. Flood hazards during construction works should be considered in the proposed CEMP.

During the operational phase, there is an increase in flood level to an existing upstream dwelling at 156 Ōpāheke Road.

The rail widening and rail over bridge geometry is located to the south of the existing road alignment. Diversion of the overland flow paths nearby and confirmation of the outlet channel path under the rail is required at the detailed design phase. The existing drain south of the corridor is potentially obstructed by the new upgrade and should be diverted to the south the enable flow conveyance towards Ōtūwairoa Stream.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Setting the levels of the new pedestrian/cycling bridges over the Ōtūwairoa Stream at the same level as the existing road bridge
- Not worsening freeboard by more than 10%, or mitigating a reduction in freeboard, to existing habitable floor levels
- Developing a management response to prevent use of the Ōtūwairoa Stream bridges during overtopping flooding events.
- Diversion of flood flows and overland flows around Ōpāheke Road wetlands 1 and 2 and providing primary drainage and overland flow capacity within the existing Ōpāheke Road corridor
- Managing the potential for Ōpāheke Road wetland 1 to be overtopped by flood flows and be subject to erosion
- If required, providing flood attenuation for corridor runoff within Ōpāheke Road wetlands 1 and 2
- That the proposed pedestrian/cycle crossings of the Ōtūwairoa Stream should be bridges

NoR D5: Ponga Road and Ōpāheke Road Upgrade – Ōpāheke Road Urban Section

There are no significant flood hazard issues associated with the construction phase of the Ōpāheke Road Urban section. Flood hazards during construction works should be considered in the proposed CEMP.

Overland flows crossing Settlement Road should be improved by new inlets and discharged into the nearby underground stormwater network. There is an opportunity for stormwater treatment and flood attenuation to be provided within the south eastern corner of the designation sought.

Key requirements for managing flooding effects are:

- The Construction Environmental Management Plan is to consider flood hazard
- Not increasing overland flows downstream of the intersection
- If required, providing flood attenuation for the increase in corridor runoff

11 References

Auckland Council (Nov 2011) Auckland Council Stormwater Modelling Specification

Auckland Council GeoMaps (accessed 2020)

Auckland Council flood models, as follows:

Available models	Drury Package projects within the catchment models
Slippery Creek (Infoworks ICM), Rapid Flood Hazard Assessment, 2018	Waihoehoe Road West FTN Upgrade (NoR D2) Waihoehoe Road East Upgrade (NoR D3) Ōpāheke N-S FTN Arterial (NoR D4), Ponga Road and Ōpāheke Road Upgrade (NoR D5)
Hingaia Stream (DHI MIKE) 1d/2d	Jesmond Road and Bremner Road FTN Upgrade sections (NoR D2)
Ngakoroa/Oira (Infoworks ICM), Rapid Flood Hazard Assessment, 2017	SH22 Upgrade (NoR D1) Jesmond Road and Bremner Road FTN Upgrade sections (NoR D2)

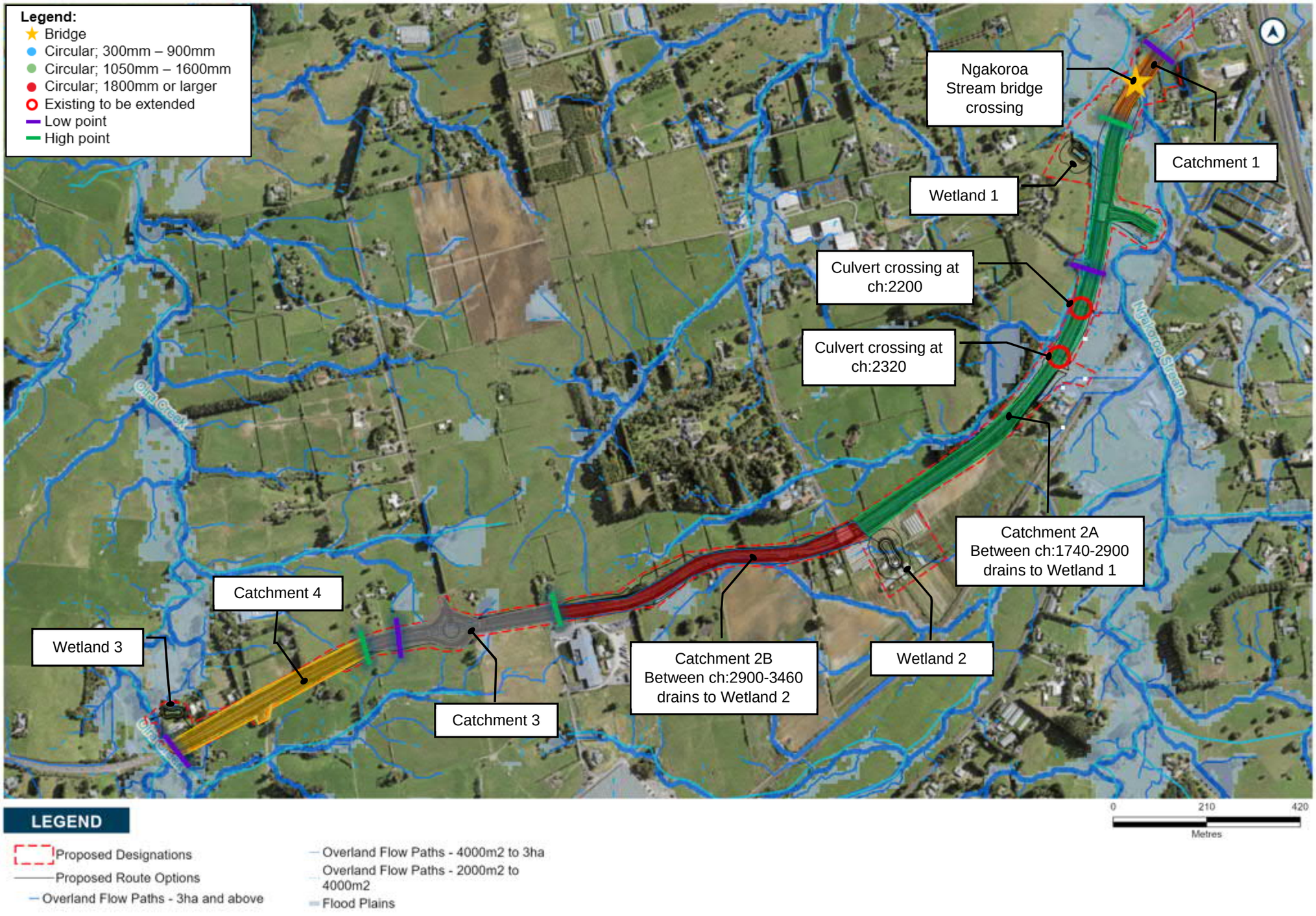
New Zealand Transport Agency (April 2016) NZTA P46 Stormwater Specification

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

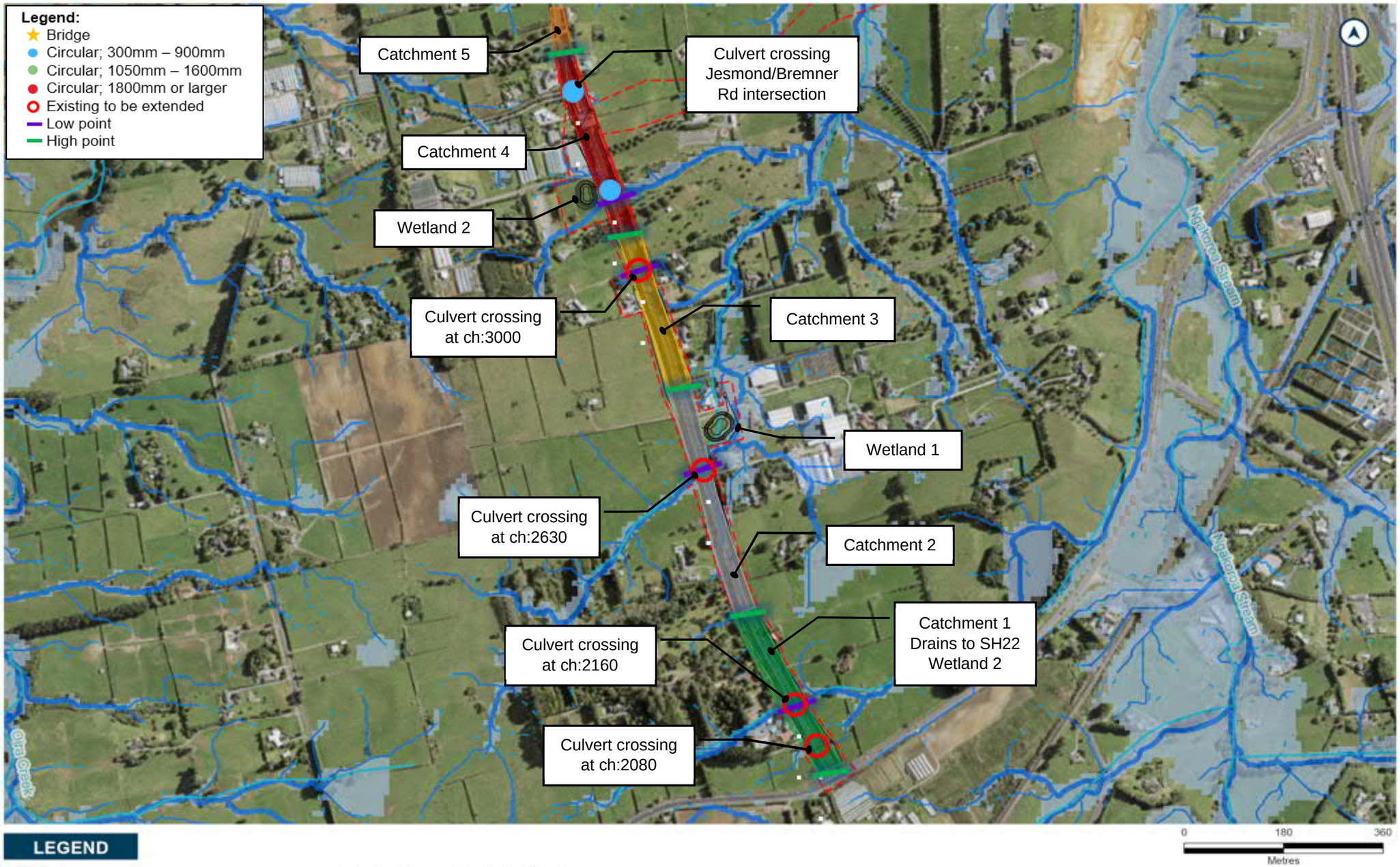
Appendix 1. Layout of Project Features

This section illustrates the stormwater catchments, treatment devices, high and low points along the transport corridor and cross drainage structures as noted in the Project Features section for each project.

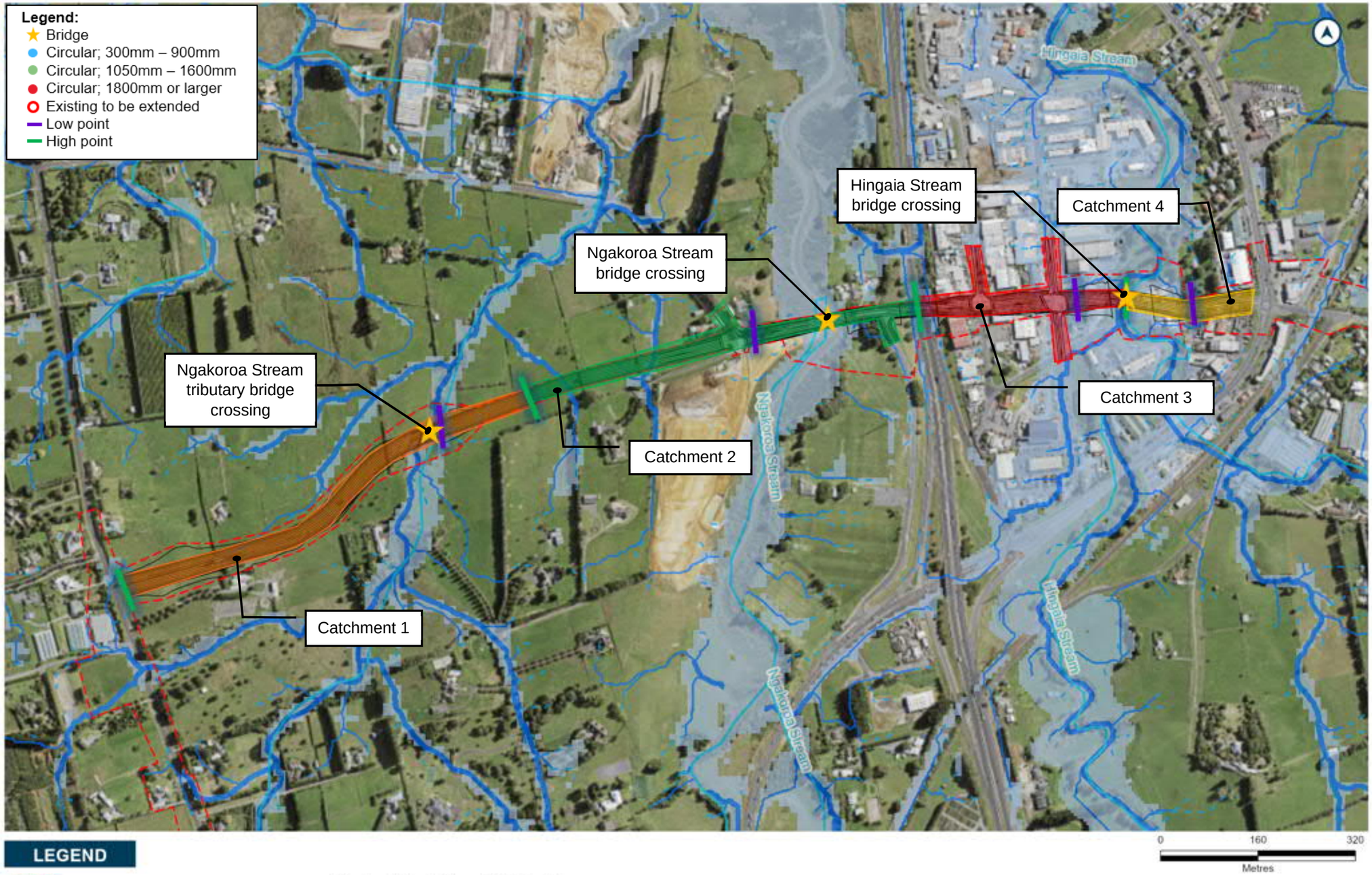
NoR D1: Alteration to NZ Transport Agency designation 6706 – State Highway 22 (SH22) Upgrade



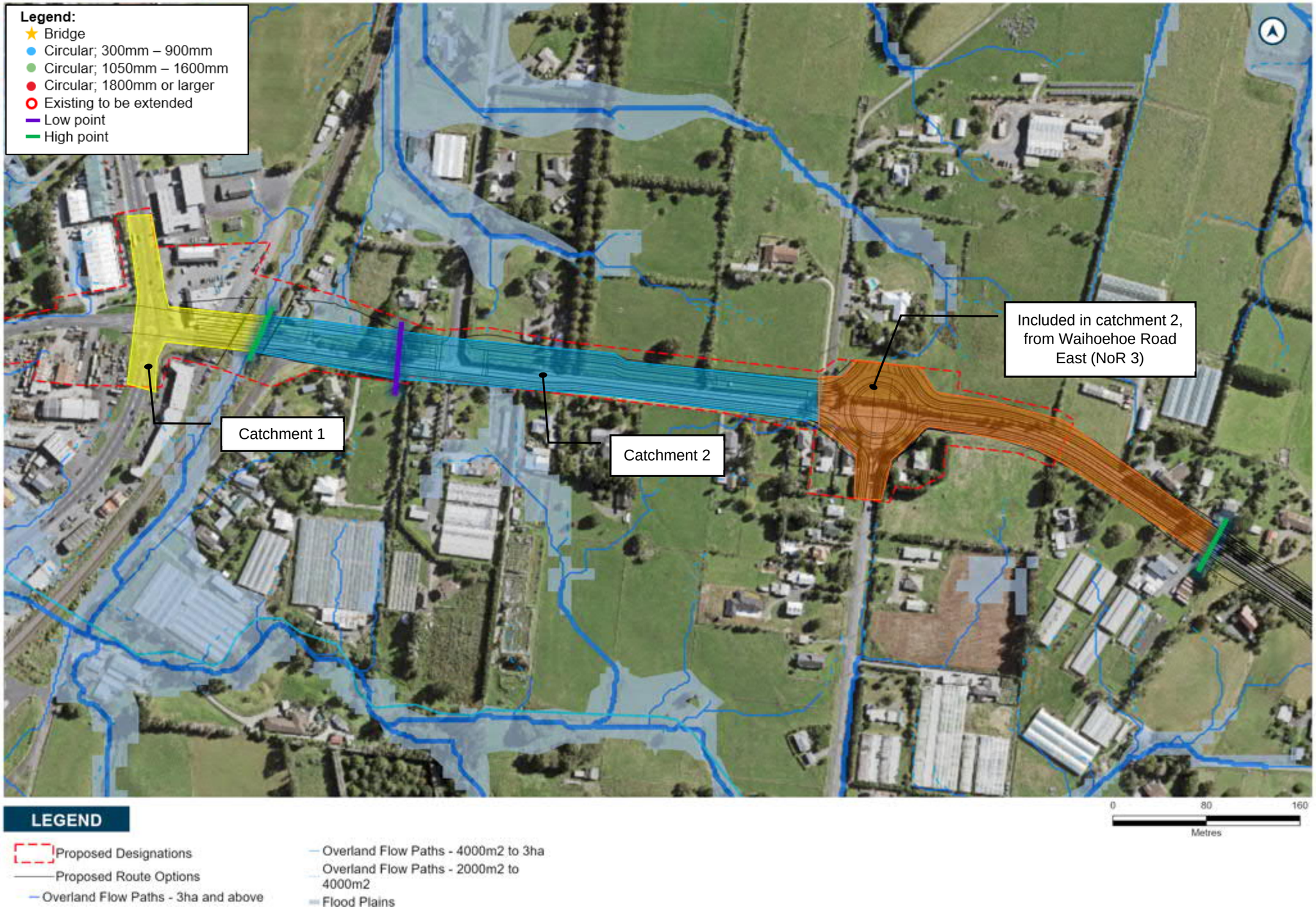
NoR D2: Jesmond to Waihoehoe West FTN Upgrade – Jesmond Road Section



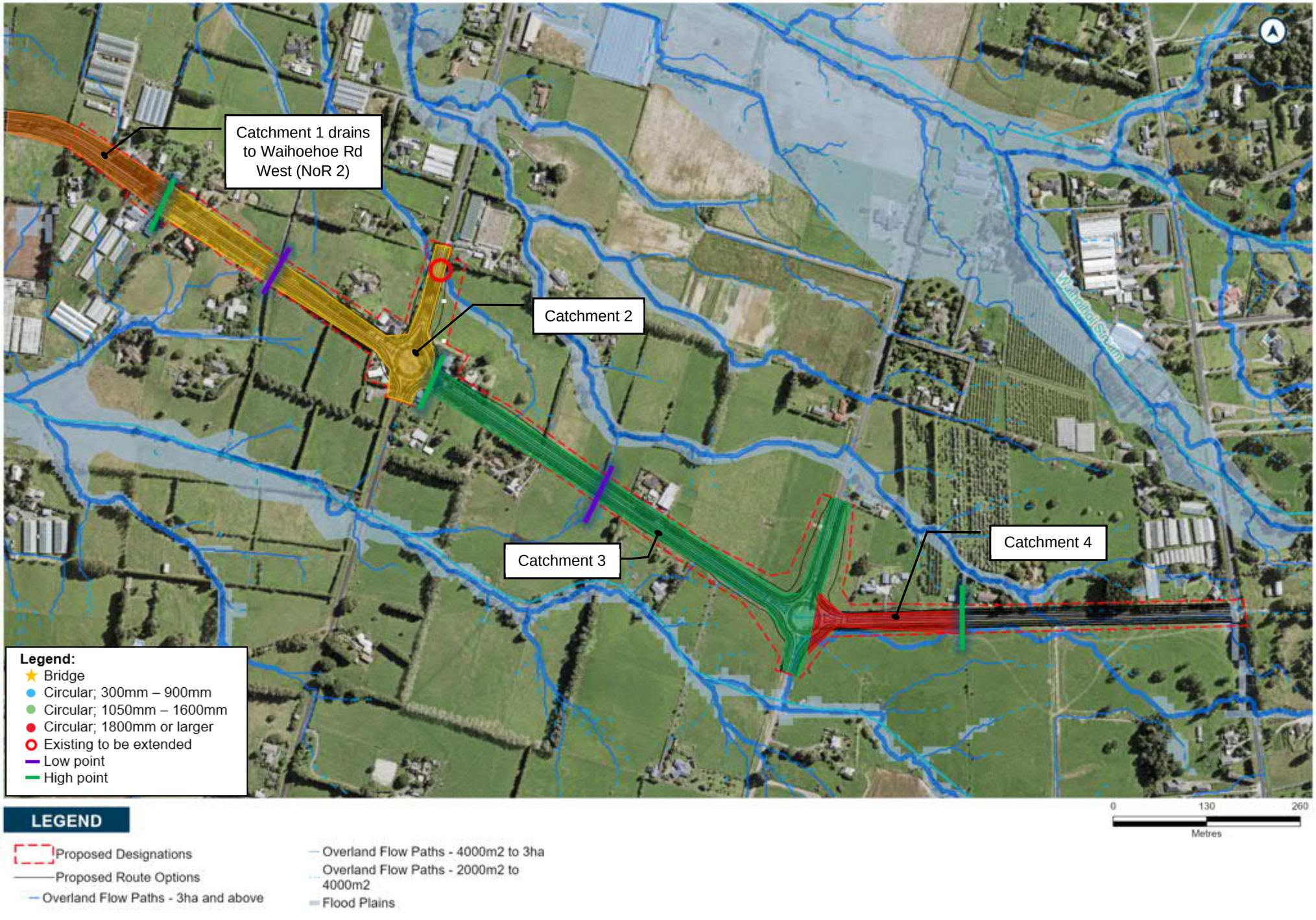
NoR D2: Jesmond to Waihoehoe West FTN Upgrade – Bremner Road Section



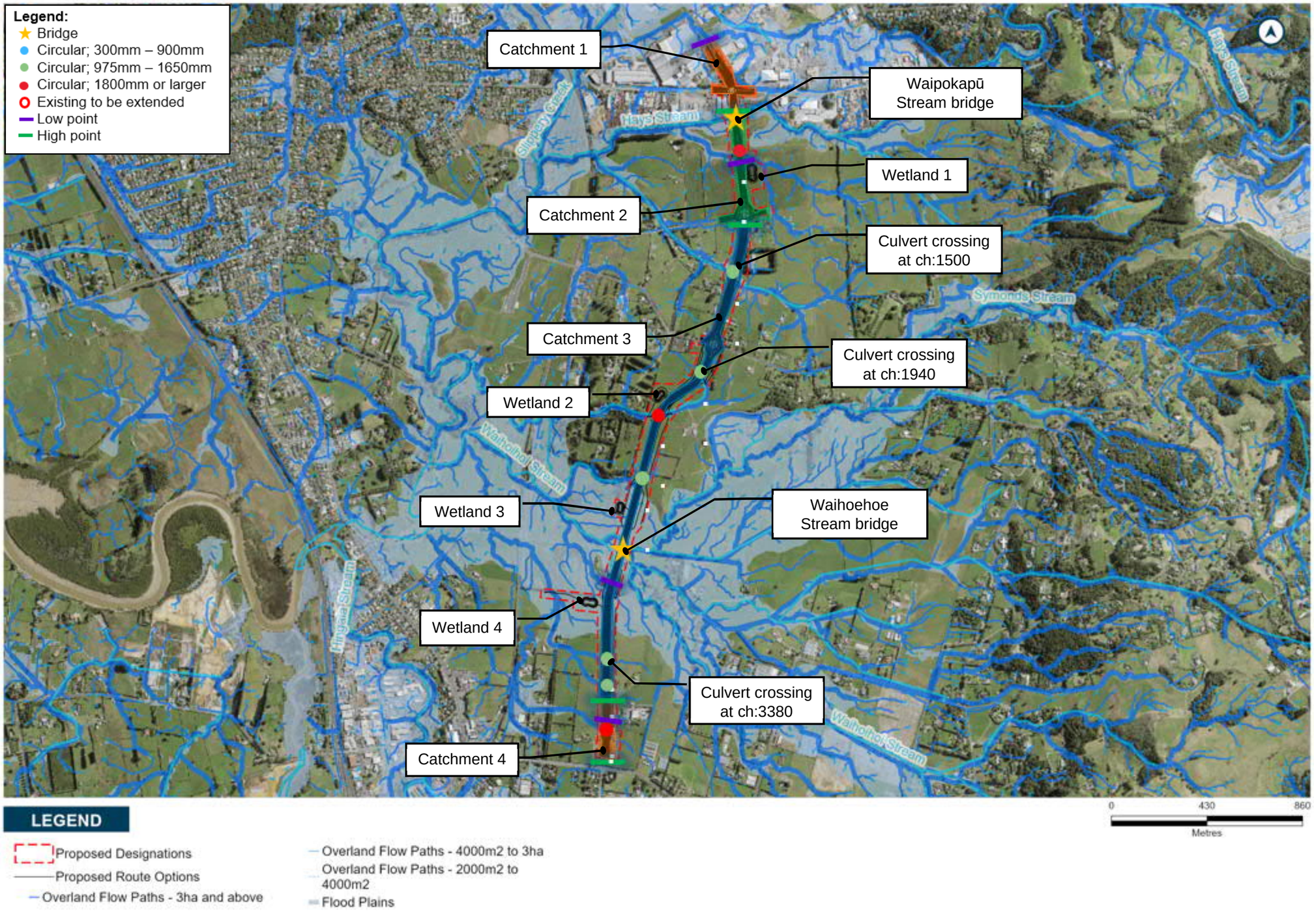
NoR D2: Jesmond to Waihoehoe West FTN Upgrade – Waihoehoe Road West Section



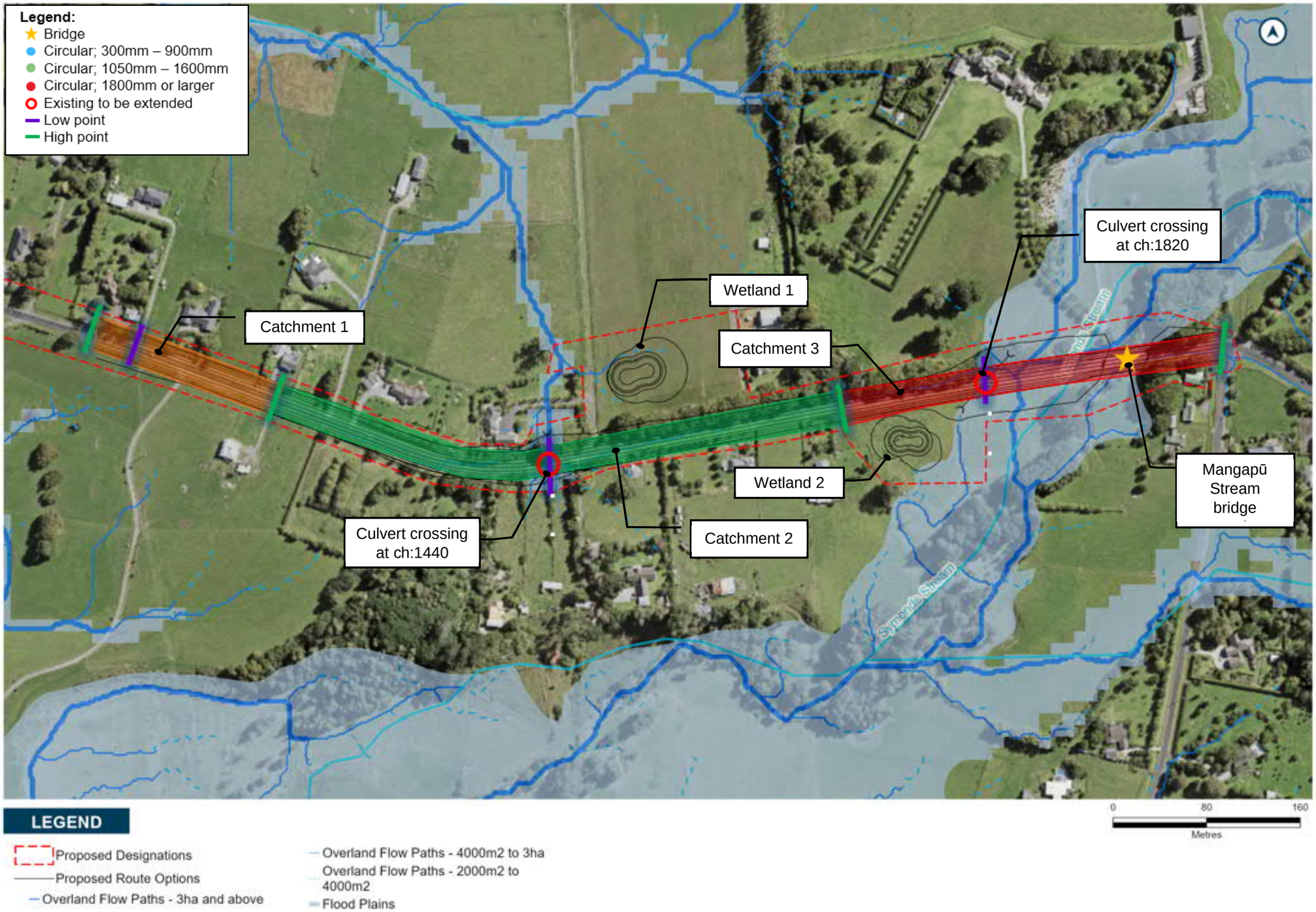
NoR D3: Waihoehoe Road East Upgrade



NoR D4: Ōpāheke N-S FTN Arterial



NoR D5: Ponga Road and Ōpāheke Road Upgrade – Ponga Road Section



NoR D5: Ponga Road and Ōpāheke Road Upgrade – Ōpāheke Road Rural and Urban Sections