NOTES

1. DO NOT SCALE OFF THESE DRAWINGS.
2. ALL DIMENSIONS AND DISTANCES ARE IN METRES UNLESS STATED OTHERWISE.
3. REFER TO DRAWING EB-2-D-3-SW-DG-000004 FOR GENERAL LEGEND AND EB-2-D-3-SW-DG-000005 FOR GENERAL NOTES.

PACKAGE No. 3SW-00

NOT FOR CONSTRUCTION

REV	DATE	DRAWN	REVISION DESCRIPTION
A	08/04/2022	M. Santos	ISSUED FOR STAGE 1 SUBMISSION

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Designed	M. Lai	Checked	P. May
Drawn	C. Tamayo	Checked	M. Dalvi
Approved	S. Jones		
Date	08/04/2022	Approver Signature	

Scale Bar: 0 – 12.5 – 25 m (A1 1:500, A3 1:1000)

KEY PLAN

AUCKLAND MANUKAU EASTERN TRANSPORT INITIATIVE
EASTERN BUSWAY ALLIANCE
(PAKURANGA TO BOTANY)

Eastern Busway

Drawing Status	
Horizontal Datum	NZGD 2000 MOUNT EDEN CIRCUIT
Vertical Datum	2016 NEW ZEALAND
A1 SCALE	1:500
A3 SCALE	1:1000
Design Package	**DRAINAGE**
Drawing Title	TI RAKAU DRIVE DRAINAGE LAYOUT PLAN SHEET 3 OF 5
Drawing Number	EB-2-D-3-SW-DG-000103
Revision	A

ORIGINAL SIZE A1

ORIGINAL IN COLOUR

Filename: EB-2-D-3-SW-DG-000101-000105.DWG

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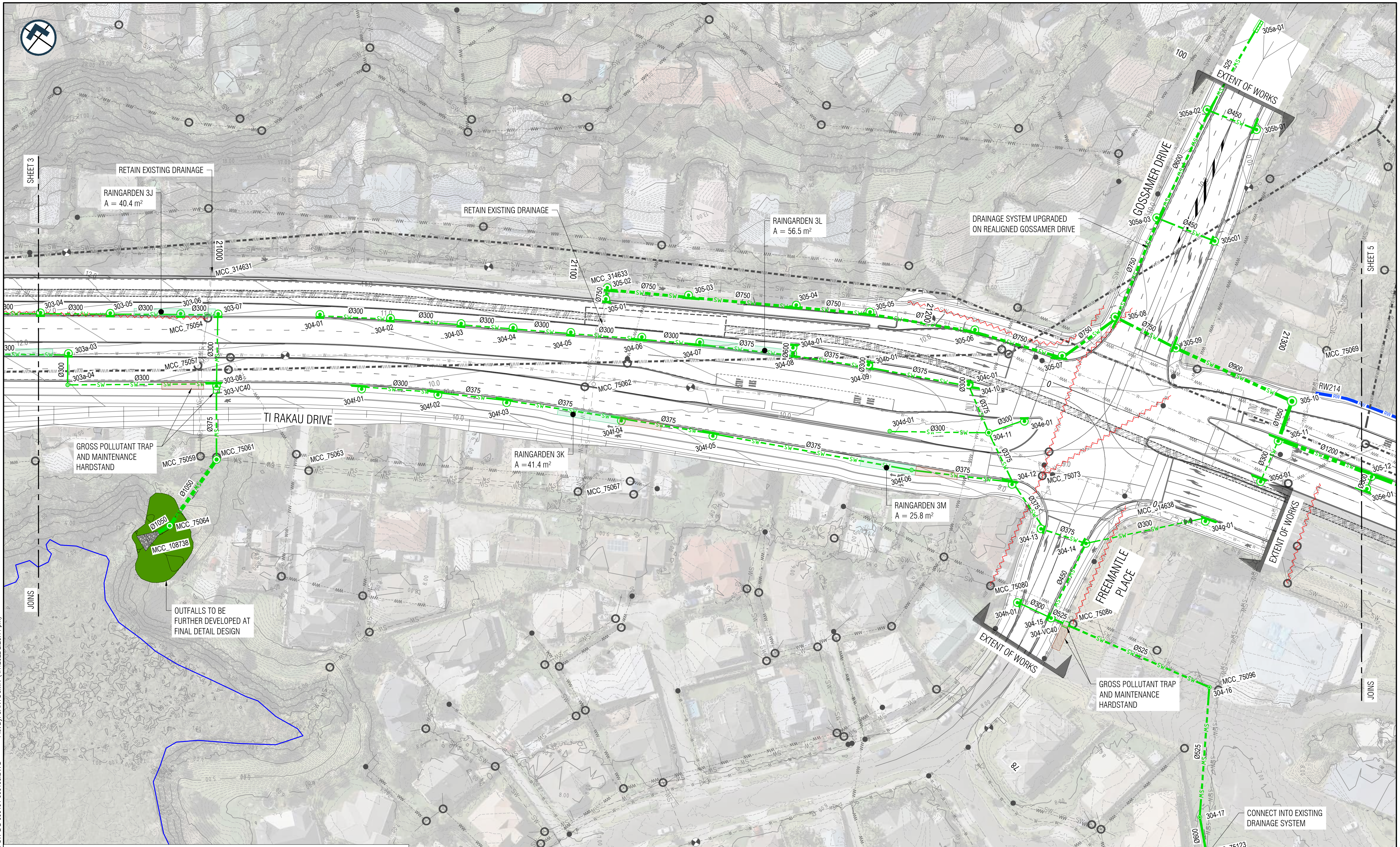

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PACKAGE No. 3SW-00

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Plot By: SANTOSMR (4/7/2022 2:26:11 pm)

Filename: EB-2-D-3-SW-DG-000101-000105.DWG

REV	DATE	DRAWN	REVISION DESCRIPTION
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Drawn	C. Tamayo	Checked	M. Dalvi
Approved	S. Jones		
Date	08/04/2022	Approver Signature	

Scale Bar: 0 12.5 25 m — A1 1:500 — A3 1:1000

KEY PLAN

AUCKLAND MANUKAU EASTERN TRANSPORT INITIATIVE
EASTERN BUSWAY ALLIANCE
(PAKURANGA TO BOTANY)

AT Eastern Busway

Drawing Status

Horizontal Datum: NZGD 2000 MOUNT EDEN CIRCUIT

Vertical Datum: 2016 NEW ZEALAND

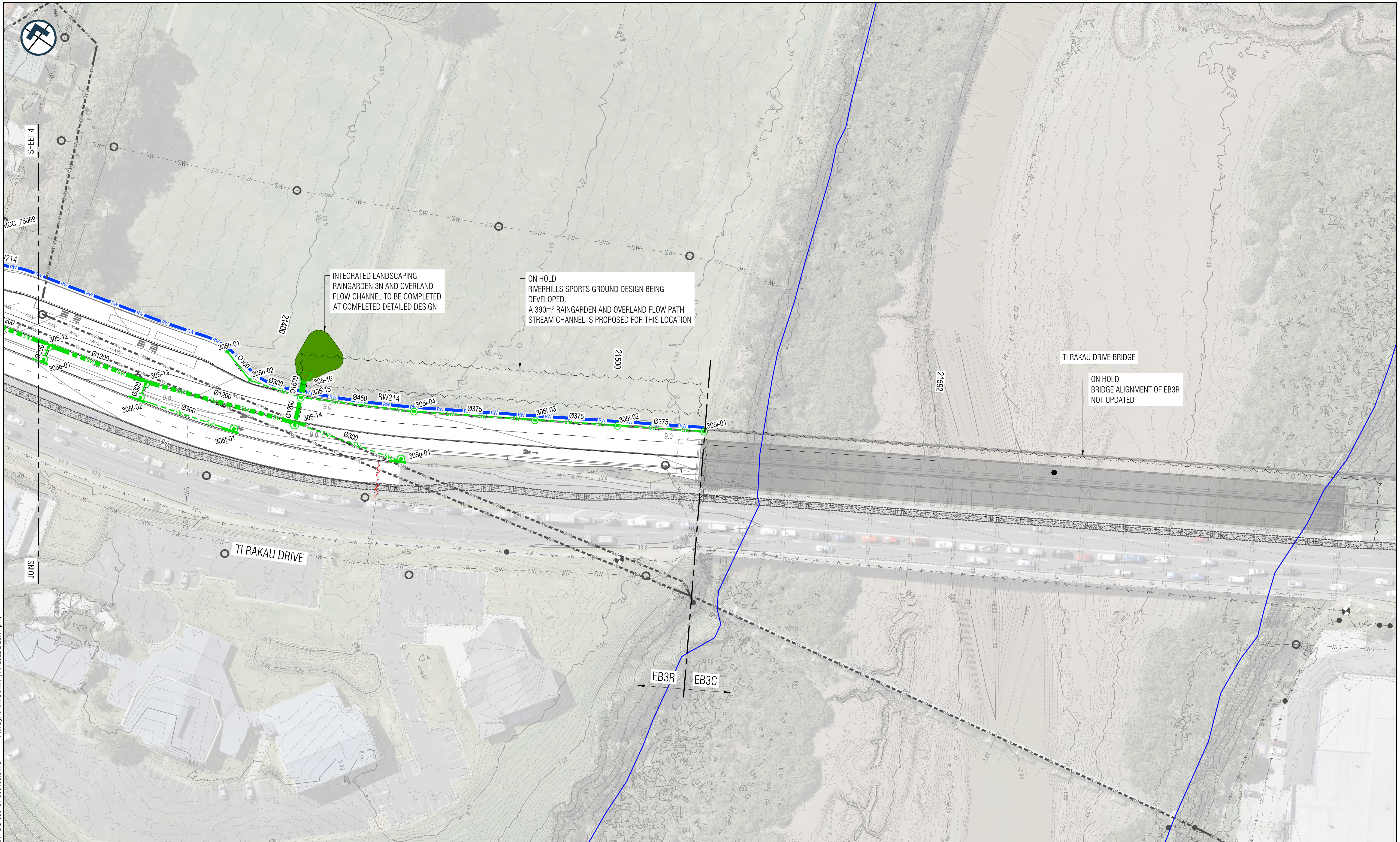
A1 SCALE 1:500 — A3 SCALE 1:1000

Design Package: DRAINAGE

Drawing Title: TI RAKAU DRIVE DRAINAGE LAYOUT PLAN SHEET 4 OF 5

Drawing Number: EB-2-D-3-SW-DG-000104

Revision: A



NOTES

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3. REFER TO DRAWING EB-2-D-3-SW-DG-000004 FOR GENERAL LEGEND AND EB-2-D-3-SW-DG-000005 FOR GENERAL NOTES.

PACKAGE No. 3SW-00

NOT FOR CONSTRUCTION

Filename: EB-2-D-3-SW-DG-000101-000105.DWG

Plot By: SANTOSMR (4/7/2022 2:26:11 pm)

REV	DATE	DRAWN	REVISION DESCRIPTION
A	08/04/2022	M. Santos	ISSUED FOR STAGE 1 SUBMISSION

A1 ORIGINAL SIZE

ORIGINAL IN COLOUR

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Drawn	C. Tamayo	Checked	M. Dalvi
Approved	S. Jones		
Date	08/04/2022	Approver Signature	

Scale Bar: 0 12.5 25 m — A1 1:500, A3 1:1000

KEY PLAN

AUCKLAND MANUKAU EASTERN TRANSPORT INITIATIVE
EASTERN BUSWAY ALLIANCE
(PAKURANGA TO BOTANY)

Eastern Busway

Drawing Status	
Horizontal Datum	NZGD 2000 MOUNT EDEN CIRCUIT
Vertical Datum	2016 NEW ZEALAND
A1 SCALE 1:500	A3 SCALE 1:1000
Design Package	DRAINAGE
Drawing Title	TI RAKAU DRIVE DRAINAGE LAYOUT PLAN SHEET 5 OF 5
Drawing Number	EB-2-D-3-SW-DG-000105
Revision	A

Appendix 4: Flood Model Build Report

Eastern Busway Flood Model Build Report

0SW-20 Flood Model

EB-2-D-0-SW-RP-200001

16-03-2022

Eastern Busway

Control

The latest version of this report is available for all Alliance staff as an electronic read-only file on the project's document control system, Procore.

Revision

Changes to the most recent revision will be highlighted. The revision number is included at the end of the document number, which is also noted in the footer of each page.

The Design Team Leader and/or the Design Manager approves revisions and re-issues.

Document history and status

The following provides the record of authorisation and revisions made to this document.

Revision	Date	Description	Author	Verifier	Approver
A	16-03-2022	For WRR Consent Package	Tom Newman	Paul May	Simon Jones

1) The current electronic version is held in Projectwise
2) The current electronic version is controlled
3) Changes to the electronic version will be notified to the Design Team leadership
4) Printed controlled copies will cease to be controlled copy once the final stage of the project has reached Practical Completion.

Distribution of copies

Revision	Date	Approver	Issued to	Comments
A	16-03-2022	Simon Jones	Planning Team	For WRR Consent Package

Terms and definitions

Table 1:Terms and definitions.

Acronym	Term	Definition
	Alliance	The alliance between the Alliance Participants formed for the delivery of Eastern Busway Stages 2, 3 and 4
AT	Auckland Transport	Auckland Transport
EBA	Eastern Busway Alliance	The name for the alliance project
1D	One dimensional	One dimensional means only one spatial dimension is considered i.e., the horizontal direction of flow.
2D	Two dimensional	Two dimensional means two spatial dimensions are considered i.e., the horizontal and lateral directions of flow.
ARC	Auckland Regional Council	Auckland Regional Council.
AEP	Annual Exceedance Probability	The probability that a given rainfall event or flow rate will be exceeded in a single year.
ARI	Average Recurrence Interval	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 pipe network, stream or watercourse at a given location.
CC	Climate Change	Climate change resulting from global warming due to greenhouse gas emissions.
CN	Curve Number	Defines the shape of the rainfall-runoff relationship and varies from 0 (no runoff) to 100 (complete rainfall) based on the underlying soil type or ground cover (imperviousness).
	Design Storm	The rainfall event calculated from historical record that can be expected for a specific AEP or ARI.
	Design Flows	The flows estimated from various design storms, selected as a basis for the design of works in watercourses and catchments.
	Drainage System	The network of pipes, streams, opens watercourses and secondary overland flow paths which carry flow within a catchment.
ED	Existing Development	The current land use development within the catchment.
EGL	Energy Grade Line	The total energy of flow at a given location, it is the sum of the elevation head, the pressure head, and the velocity head.
	Energy Loss	Energy or head loss occurs due to frictional resistance, contraction and expansion at entrance and exit, change in flow direction, change in elevation, and change in cross-section.
	Floodplain	The plan extent of flooding in a given AEP or ARI storm.
	Flood Sensitive Area	The plan extent of flooding for 500mm (freeboard) above the 100-year ARI flood levels.
	Freeboard	Design margin to allow for factors omitted in the overall design (e.g., uncertainties in flood level estimation, wave action, and localised water level variations).
GIS	Geographical Information System.	Geographical Information System, typically software such as ArcMap.

HGL	Hydraulic Grade Line	A line coinciding with the level of flowing water in an open channel. In a closed conduit flowing under pressure, the HGL is the level to which water would rise in a vertical tube at any point along the pipe. It is equal to the energy grade line (EGL) elevation minus the velocity head.
	Hydrograph	A graph illustrating the variation of flow with time.
	Hydrological Soil Group	Soil classification (A, B, C, or D) according to infiltration rate, where A is very high infiltration and D is very poor infiltration.
IA	Initial Abstraction	Rainfall losses occurring before runoff begins, includes water retained in surface depressions, intercepted by vegetation, evaporation, and infiltration.
LiDAR	Light Detection and Ranging survey	Light Detection and Ranging survey used to create ground models of the terrain.
	Link	Link represents stormwater drainage pipes, culverts, bridges, stream channel reaches or overland flow paths.
	Manning's "n"	Manning's roughness coefficient to account for energy losses due to frictional resistance to flow.
MPD	Maximum Probable Development	The ultimate future land use development which will proceed up to the maximum permitted under the current District Plan.
	Node	Node represents the drainage system attributes such as manholes, inlets, outlets, junction between open channels, ponds.
	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.
	Runoff	The fraction of rainfall which runs off the land surface to the drainage system.
	Sub-catchment	A smaller sub-area of the catchment draining to a watercourse.
ToC	Time of Concentration	Time for a water particle to travel from the hydraulically most distant point of a catchment to the outlet.
	Topography	Forms and features of land surfaces.
TP108	TP108	Auckland Regional Council Technical Publication 108.
	Unit Hydrograph	Hydrograph produced by a unit depth of rainfall excess falling uniformly in time and space over a unit area catchment.

Executive summary

Flood modelling has been undertaken to ascertain the existing flood risk to and potential impacts of the Eastern Busway development.

The purpose of this document is to provide details on the flood model build, methodology and results (i.e. maps). Analysis and interpretation of the results is provided in each stormwater effects assessment of the Eastern Busway consent packages. This report is issued to support the stormwater effects assessment for William Roberts Road (WRR) and will be progressively updated as the other Eastern Busway sections are ready for resource consent applications. This report will also be progressively updated throughout the detailed design process to document impacts of design changes and verify the project meets conditions of resource consents and/or Auckland Council Healthy Waters connection requirements under the Network Discharge Consent (NDC).

The four stormwater effects assessments documents are:

- WRR Early Works Package (completed and included in this report)
- Eastern Busway 2 (EB2) and Eastern Busway 3 Residential (EB3R) Package (completed)
- Eastern Busway 3 Commercial (EB3C) (awaiting outcome of public consultation)
- Eastern Busway 4 (EB4) (awaiting outcome of multicriteria assessment)

Flood Maps from the modelling are provided in following nine appendices:

- Appendix 1 EB2 flooding assessment (base and design case) flood maps
- Appendix 2 WRR flooding assessment (temporary design case) flood maps
- Appendix 3 EB3R flooding assessment (base and design case) flood maps
- Appendix 4 EB3C flooding assessment (base and design case) flood maps
- Appendix 5 EB4 flooding assessment (base and design case) flood maps
- Appendix 6 EB2 overland flow path assessment (base and design case) flood maps
- Appendix 7 EB3R overland flow path assessment (base and design case) flood maps
- Appendix 8 EB3C overland flow path assessment (base and design case) flood maps
- Appendix 9 EB4 overland flow path assessment (base and design case) flood maps

The Eastern Busway modelling utilised two existing Auckland Council models; Tamaki River – Pakuranga SW model and Pakuranga Creek SW model. These existing models were trimmed to the catchment extent required to assess the impacts of the Eastern Busway design. The trimmed models were split between EB2 – EB3R and EB3C – EB4, essentially at Pakuranga Creek.

The existing models were used to develop a base case model to ascertain the existing flood risk. The most significant changes to the base case models include updating the LiDAR to 2016, using a 25 cm cell size around the Eastern Busway designation, and converting the projection to NZDG 2000 Mount Eden circuit and vertical datum to NZVD 2016.

The base case model was used to extract flow rates and flow paths to assist in determining where design stormwater networks would be required.

Design stormwater networks and geometrics were added to the base case model to create a design model. This report explains differences in the design model from the proposed design. The purpose of the deviations from the proposed design was to establish what would be required to maintain existing flood risk to third party properties. These deviations from the design are to be refined and amended in the detailed design stage.

The design model results were used to compare differences in flow rate, flow paths, and water level from the base model results. Comparing design to base case model results established areas where increased flood risk was to determine where design pipe upsizing would be required to maintain or reduce the predicted flood risk.

Contents

1. Introduction

1.1 Package summary

A flood assessment was undertaken for Eastern Busway (EB) in order to ascertain the existing flood risks and the effects the proposed EB design would have in each of the four EB zones:

- EB2
- EB3R (Residential)
- EB3C (Commercial)
- EB4

The EB flood modelling was split across two catchments:

- EB2 – EB3R: Pakuranga – Tamaki River catchment
- EB3C – EB4: Pakuranga Creek catchment

The flood model extents are shown Figure 1.

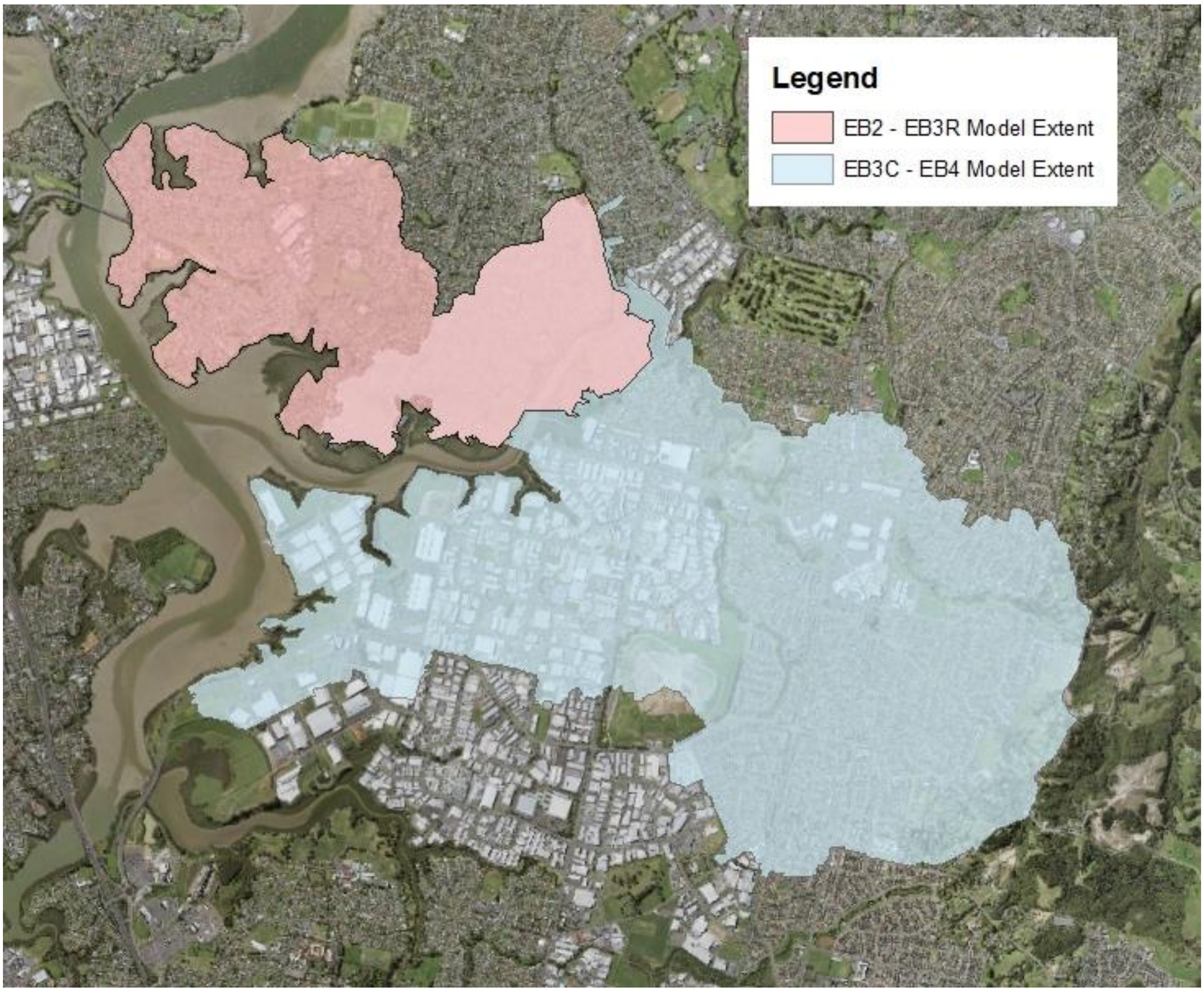

Figure 1: Eastern Busway flood model extents.

1.2 Scope of design package

1.2.1 Items covered in report

The scope of this flood assessment comprised of the following:

- Convert the existing Tamaki River – Pakuranga and Pakuranga Creek flood models to NZGD 2000 Mount Eden Circuit XY projection and NZVD 2016 Z projection
- Trim the models to the areas of interest and undertaken any changes required to develop a baseline flood risk assessment
- Update the LiDAR to 2016
- Add the new design terrain and stormwater pipe network
- Assess the effects of the EB design to maintain flood neutrality compared to the updated baseline flood risk assessment

This Revision A report includes the following:

- Completed EB2 flooding assessment (base and design cases) (see Appendix 1)
- Completed WRR flooding assessment (base and design cases) (see Appendix 2)
- Completed EB3R flooding assessment (base and design cases) (see Appendix 3)
- Completed EB2 overland flow path assessment (base and design cases) (see Appendix 6)
- Completed EB3R overland flow path assessment (base and design cases) (see Appendix 7)

Flood modelling has generally been carried out in accordance with TP 108 – Guidelines for stormwater runoff modelling in the Auckland Region (April 1999), the Auckland Council (AC) Modelling Methodology (November 2011) and the Auckland Council Code of Practise Version 3 January 2022. Any differences from these documents have been detailed and discussed within this report.

1.2.2 Items not covered in report

This Revision A report excluding the following:

- EB3C flooding assessment (base and design cases) (see Appendix 4)
- EB4 flooding assessment (base and design cases) (see Appendix 5)
- EB3C overland flow path assessment (base and design cases) (see Appendix 8)
- EB4 overland flow path assessment (base and design cases) (see Appendix 9)

1.3 Package's contributions towards project objectives

The package documents the flood model build, methodology and results (i.e. maps). These models and flood maps will be used to inform the design so that changes can be made where necessary to achieve flood neutrality compared to the updated baseline flood risk. This report, the models and the flood maps are also used to develop the assessment of stormwater effects documents for each of the four consent packages (WRR, EB2/EB3R, EBC3 and EB4).

2. Changes since last submission

This Revision A report of the flood model build report sets the baseline for documenting future changes. This section will be updated for each future revision.

3. Flood assessment

3.1 Project requirements

The basis of the EB design aims to achieve:

- Flooding neutrality for the predicted flood effects during the future 100-year rainfall event between the EB design model and base models
- The project minimum requirements (MRs)

3.2 Assumptions and Limitations

Key assumptions in relation to the flood modelling are provided in Table 2

Table 2: Key flood modelling assumptions.

No.	Item	Assumption
1	Existing Drainage System	The existing drainage network was taken from the Tamaki and Pakuranga models that have been reviewed and accepted by Auckland Council.
2	Tamaki and Pakuranga models	The assumptions and limitation shown in the Tamaki River – Pakuranga and Pakuranga Creek Model Builds accepted by Auckland Council are also relevant to this project. The assumptions and limitations taken from those reports has been added under Appendix 10.
3	Hydraulic Modelling	Has been based on the approved Tamaki and Pakuranga models and changes through model changes, site inspections or design improvements.
4	Existing catchpit capacity	Existing catchpits (where modelled) are assumed to have an inlet capacity of 25 L/s unless site visits indicated greater capacity may be relevant.
5	Ground Levels	Proposed ground levels have been taken from EB designs and used in the modelling. Existing ground levels have been taken from the EB natural surface.
7	Future rainfall events	The 10 and 100-year future rainfall events have been based on TP108 and the AC Code of Practice (CoP) Version 2 (dated Nov 2015) which also equally applies to Version 3 Jan 2022.
8	Building connections	Private drainage in separated areas (non-soakage) are connected to the nearest pipe to the site without crossing neighbouring private property. In some cases, the discharge is directly to the nearest road kerb line.
9	TP108 Rainfall	Modelling is limited by the ARC TP108 rainfall-runoff model which is expected to be within ± 25% at a confidence level of 90 percent for 2-year to 100-year ARI storm events (ARC, 1999).
10	Sub-catchment runoff	All sub-catchment runoff was assumed to enter freely into the reticulation system i.e., catch pit inlet control was modelled for stormwater reticulation as 2D gully type nodes where a maximum 100 litres per second was allowed, the excess runoff is diverted to the 2D ground model. The model

		effectively assumes catch pit inlet capacity is equal to or greater than the modelled pipe capacity.

3.3 Models referred to in this report

There are six SW models that are discussed in this report:

- Tamaki River – Pakuranga SW (Tamaki) Model as accepted by AC Healthy Waters (01/06/2016). This model uses the existing SW network and terrain based on 2013 LiDAR
- Pakuranga Creek SW (Pakuranga) Model as accepted by AC Healthy Waters (20/02/2017). This model uses the existing SW network and terrain based on 2013 LiDAR
- EB2 – EB3R Base Model based on a combined and trimmed version of the Tamaki and Pakuranga SW Models and changes to produce a baseline flood assessment
- EB3C – EB4 Base Model based on a trimmed version of the Pakuranga SW Model and changes to produce a baseline flood assessment
- EB2 – EB3R Design Model based on EB2 – EB3R Base Model with the design ground model and stormwater pipe and manhole network
- EB3C – EB4 Design Model based on EB3C – EB4 Base Model with the design ground model and stormwater pipe and manhole network
- The EB2-EB3R and EB3C-EB4 models are trimmed from the Tamaki River – Pakuranga and Pakuranga Creek models shown in Figure 2 and are updated with terrain based on 2016 LiDAR

3.4 Model runs

Numerous versions of the EB2 – EB3R and EB3C – EB4 design models have been run at different stages of the EB project development:

- Mitigation Design – the EB design with mitigation measures to prevent increased flood risk to third party properties
- MR Compliant Design – EB design with increased network capacity to reduce flood <10 mm in a 10-year event and <100 mm in a 100-year event
- William Roberts Road temporary connection run – the EB2 – EB3R model was run with a temporary stormwater connection as detailed in this report
- Overland Flow Path run – the existing and design EB models were run with a reduced pipe capacity to simulate pipe capacity reduction to compare changes in overland flow paths

This report details model build methodology for all of the model runs listed above. However, flood model results at this stage are discussed only for the William Roberts Road temporary connection model run. The other model runs will be progressively updated for each consenting package.

This report details deviations from the design at the time of the modelling in order to determine what would be required in principle to achieve mitigation and MR compliance. These deviations will be reviewed and amended in the detailed design stage.

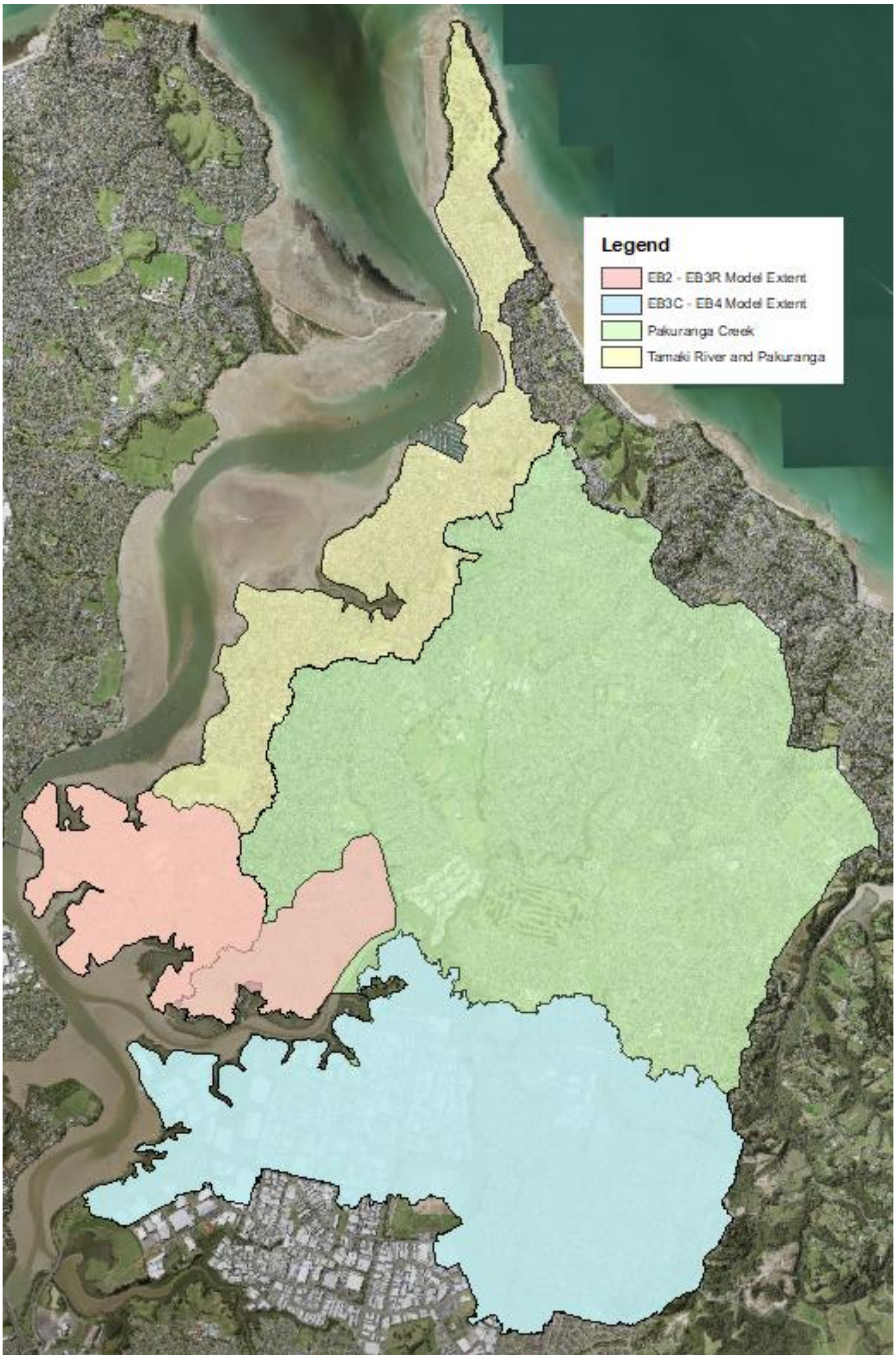

Figure 2: Eastern Busway and Auckland Council flood model extents.

3.5 Design and modelling philosophy

3.5.1 Rainfall and boundary conditions

The Auckland Council Code of Practise requires that stormwater catchment runoff follows the guidelines outlined in the Auckland Regional Council Technical Publication (TP) No. 108 (ARC, 1999).

The key features of the TP108 rainfall-runoff model are:

- A standard 24-hour temporal rainfall pattern with peak rainfall occurring halfway through the storm event
- Runoff depth calculated using Soil Conservation Service (SCS) rainfall-runoff curves, with curve numbers determined from the SCS guidelines according to classifications assigned to Auckland soil types
- Runoff hydrograph calculated using the standard SCS synthetic unit hydrograph
- Time of concentration estimated using an empirical lag equation derived from a regression analysis of data from the Auckland Region

TP108 existing rainfall depth contours for the existing 10 and 100-year rainfall contours are shown in Figure 3.

Table 3 shows the maximum rainfall that was used in the Tamaki River – Pakuranga and Pakuranga Creek models which was applied to the EB2 – EB3R and EB3C – EB4 models. These rainfall values will be updated in the detailed design phase to better represent the rainfall contours in the truncated EB2 – EB3R and EB3C – EB4 models.

Table 3:Model maximum rainfall.

Eastern Busway Zone	10-year Maximum Rainfall (mm/hour)	100-year Maximum Rainfall (mm/hour)
EB2	102.1	162.04
EB3R	107.1	165.65
EB3C	107.1	165.65
EB4	107.1	165.65

The rainfall from Table 3 accounts for a climate change allowance of 13.23% for the 10-year ARI event and 16.8% for the 100-year ARI event. These climate change allowances are from the Stormwater Code of Practice Version 2 but also remain the same in the version 3 of the document as of January 2022.

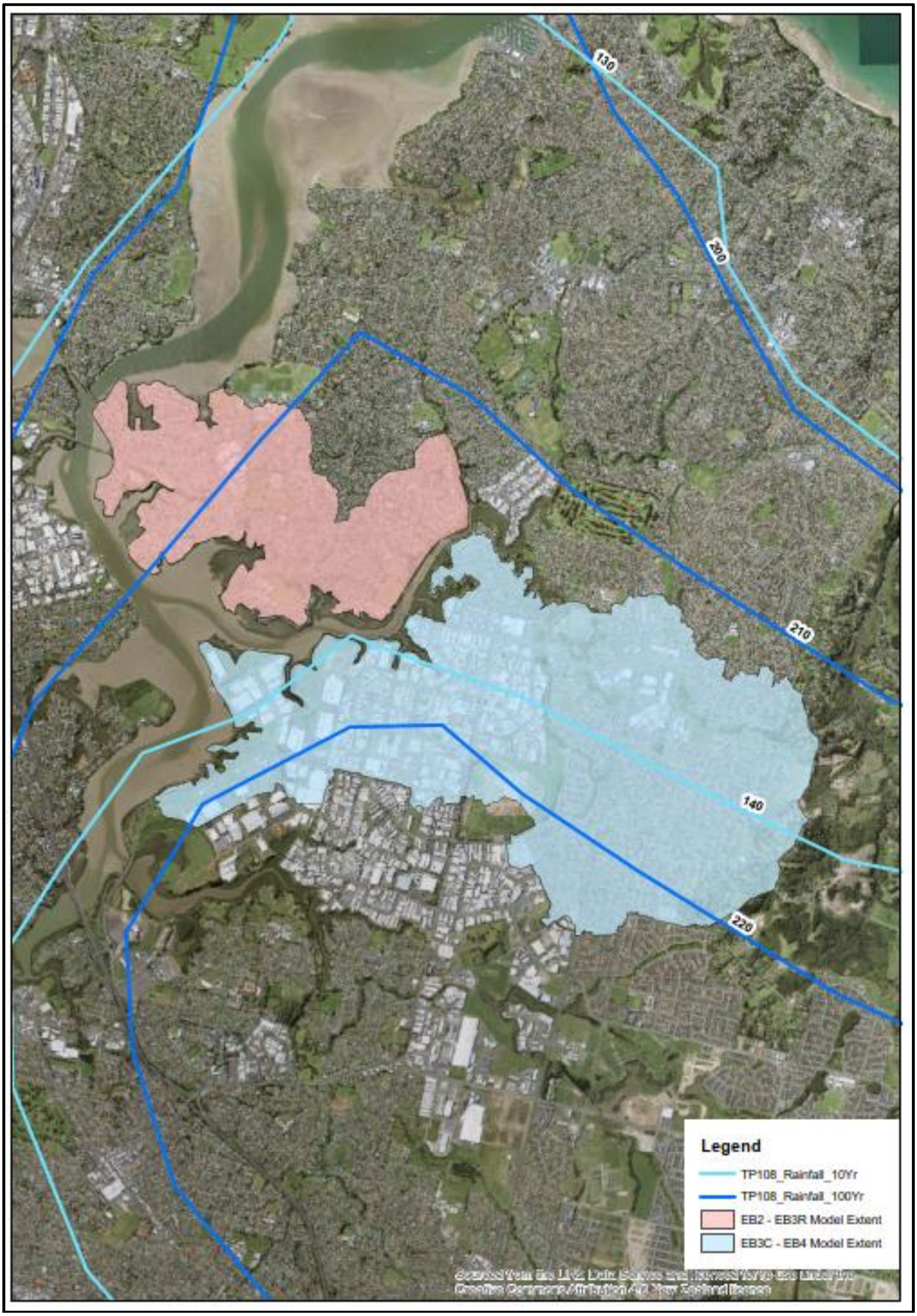

Figure 3: TP108 rainfall depth contours.

The rainfall in the models used a standard 24-hour temporal rainfall pattern shown in Table 4.

Table 4: 24-hour storm temporal pattern.

Time From	Time To	Normalised Intensity (mm)
00:00	06:00	0.33
06:00	09:00	0.73
09:00	10:00	0.95
10:00	11:00	1.40
11:00	11:30	2.20
11:30	11:40	3.82
11:40	11:50	4.86
11:50	12:00	8.86
12:00	12:10	16.65
12:10	12:20	5.95
12:20	12:30	4.24
12:30	13:00	2.92
13:00	14:00	1.70
14:00	15:00	1.19
15:00	18:00	0.75
18:00	00:00	0.39

Rainfall losses were applied to individual sub-catchments (pervious and impervious) within the two ICM models.

Sub-catchments in the base models were imported from the Tamaki River – Pakuranga and Pakuranga Creek models which were delineated in ArcGIS software based on 2013 LiDAR, overland flow paths and stormwater pipe networks as per the AC models. The sub-catchments are typically between 0.1 to 3 ha. Some of the imported sub-catchments were split due to size or additional existing pipe network being imported into the base models.

In the design models, sub-catchments within the Eastern Busway extents were created in 12D using design geometrics and stormwater pipe networks. The sub-catchments outside of the busway extent are typically between 0.1 to 3 ha with sub-catchments within the busway extent being as small as 0.004 ha. The impervious area within the sub-catchments in the cropped model was calculated in ArcGIS using road and building outlines from LINZ for the base case.

TP108 methodology uses SCS Curve Number (CN) and Initial Abstraction (IA) to describe rainfall losses. These are based on soil types and land use.

An initial abstraction of 5 mm was applied to pervious areas whereas an initial abstraction of 0 mm was applied to impervious areas. Initial abstraction was not changed outside the busway extent where impervious area had not changed.

Soil types A, B and C are within the Pakuranga Creek and Tamaki River and Pakuranga catchments which correspond to volcanic soils, alluvial sediments, and Waitemata soils respectively. In the Tamaki River and Pakuranga catchment, a SCS CN of 39 for Group A, 61 for Group B and 74 for Group C were used for pervious areas and a CN of 98 was used for impervious areas. In the Pakuranga Creek catchment, a SCS CN of 61 for Group B and 74 for Group C were used for pervious areas and a CN of 98 was used for impervious areas.

The sub-catchment time of concentration was checked with the majority being 10 minutes whilst up to 8% were between 10 and 20 minutes in the EB2 – EB3R model and up to 22% were between 10 and 25 minutes in the EB3C – EB4 model.

The future tidal boundary of RL2.43 m (NZVD2016) has been applied at all network outlets in both models which includes 1 m for sea level rise in accordance with the climate change section of the Auckland Council Stormwater Code of Practice (Versions 2 and 3).

3.5.2 Software version

All models use Innovyze ICM version 11.0.5.22025.

3.5.2.1 Model extents

The Tamaki and Pakuranga models were trimmed to the extent shown in Figure 1. This was done to reduce run times by excluding running areas of the model that did not affect flow or flooding effects within the Eastern Busway designation.

3.5.3 Model data

The base and design models were converted to NZGD 2000 Mount Eden Circuit projection with NZVD 2016 vertical datum. The conversion included stormwater network asset data, open channels, and boundary levels.

A 0.25 m grid was developed from 2016 LiDAR natural surface terrain being used by the geometrics designers. A 0.25 m^2 mesh zone was applied across the road corridor in both base and design case models to provide a higher resolution to represent the proposed road design. All other areas of the model had a mesh size between 2 and 4 m^2.

Due to the small mesh size, the 2D element factor was increased from one to four in both base and design models. This allows for water from up to four calls to flow into the catchpits. This change was made due to inflow to the catchpit being restricted by the connected 2D area of a single cell.

3.5.4 Design LiDAR

The design LiDAR used the 2016 LiDAR natural surface used in the existing model and burned the design on top to represent changes in geometrics along the road corridor. The interface between the design and the existing ground were checked to ensure there was a match at the boundary of the two terrains.

In EB2, the flyover embankments are represented in the 2D ground model. The flyover itself is not represented with Reeves Road ground level beneath the flyover represented instead. The flyover piers are represented using mesh level zones.

Reeves Road stormwater network includes raingardens in the centre of the road, under the flyover. These raingardens are small channels represented using mesh level zones to connect the down pipes from the flyover to the Reeves Road stormwater pipes.

The stormwater network includes trapezoidal channels around the flyover embankment at Pakuranga Highway and along Ti Rakau Drive along Riverhills Park. These channels have been burned into the terrain using GIS.

The design ground model includes two 40 m wide 'channels' on Ti Rakau Drive, southeast of Ti Rakau Park, shown in Figure 4. These channels were lowered to existing ground level to maintain existing overland flow paths. This was to assess the changes in geometrics design required to remove increased flooding to properties along the north of Ti Rakau Drive due to overland flow issues and is subject to changes in detailed design. Where geometrics cannot be lowered to existing ground levels in these channel areas, additional pipe network will be added to convey the flow.

Figure 4: Two 40 m wide existing ground level channels in the design model.

3.5.5 Sub-catchments

Sub-catchments in the base models were reviewed. Large catchments were separated to allow for loading into adjacent pipes.

Sub-catchments around Botany Town Centre (EB3C – EB4 model) were split based on available private drainage plans.

In the design models, sub-catchments along the road were incorporated based on the 12D design. Existing base case sub-catchments that may have previously crossed and included the road were split to include an upstream portion, road sub-catchments and downstream portion. The overall sub-catchment areas for cases where the base case covered the road were checked to ensure overall sub-catchment areas were maintained.

Sub-catchment area was calculated in GIS and 100% of the sub-catchment area contributed to rainfall (pervious and impervious). Checks were made to ensure that the contributing areas and catchment areas in ICM were the same as issues can arise with splitting and reassigned catchments.

In the EB2-EB3R design model, sub-catchments along the Reeves Road flyover are loaded to the pipe network on the ground. This model allows for the flyover 100-year flows to be diverted to the bridge downpipes into the drainage network below the bridge. The downpipes have been designed to convey the 20-year flow. Therefore, flow going to Reeves Road is currently overestimated and flow to both flyover embankments is underestimated.

The Reeves Road flyover will be amended in the detailed design phase by applying the 20-year rainfall to the current sub-catchments shown in green in Figure 5. The remainder of the 100-year rainfall (the hydrograph where flow is greater than the 20-year maximum flow) will then be applied to the sub-catchments shown in blue where overland flow goes towards Pakuranga Highway. These sub-catchments are split between west and east bound lanes although the ground model does not represent the flyover, only the embankments. Lag time on the flyover will be calculated from the elevation difference of the highpoint to the loading nodes at the low points and the distance between the two.

Figure 5: Flyover sub-catchments loaded to downpipes (green) and flyover sub-catchment to be loaded to the pipe network to the west in the detailed design stage (blue).

Pipe networks in the abutments, at each end of the flyover, have been modelled along with catchpits to take road sub-catchment flows. Each of the flyover embankment catchpit sub-catchments is loaded to that catchpit and excess flow then flows to the next downstream catchpit or inlet.

Additional sub-catchments are added to the design EB3C – EB4 model to represent the widened Ti Rakau Drive bridge and busway behind China Town shopping mall shown in Figure 6.

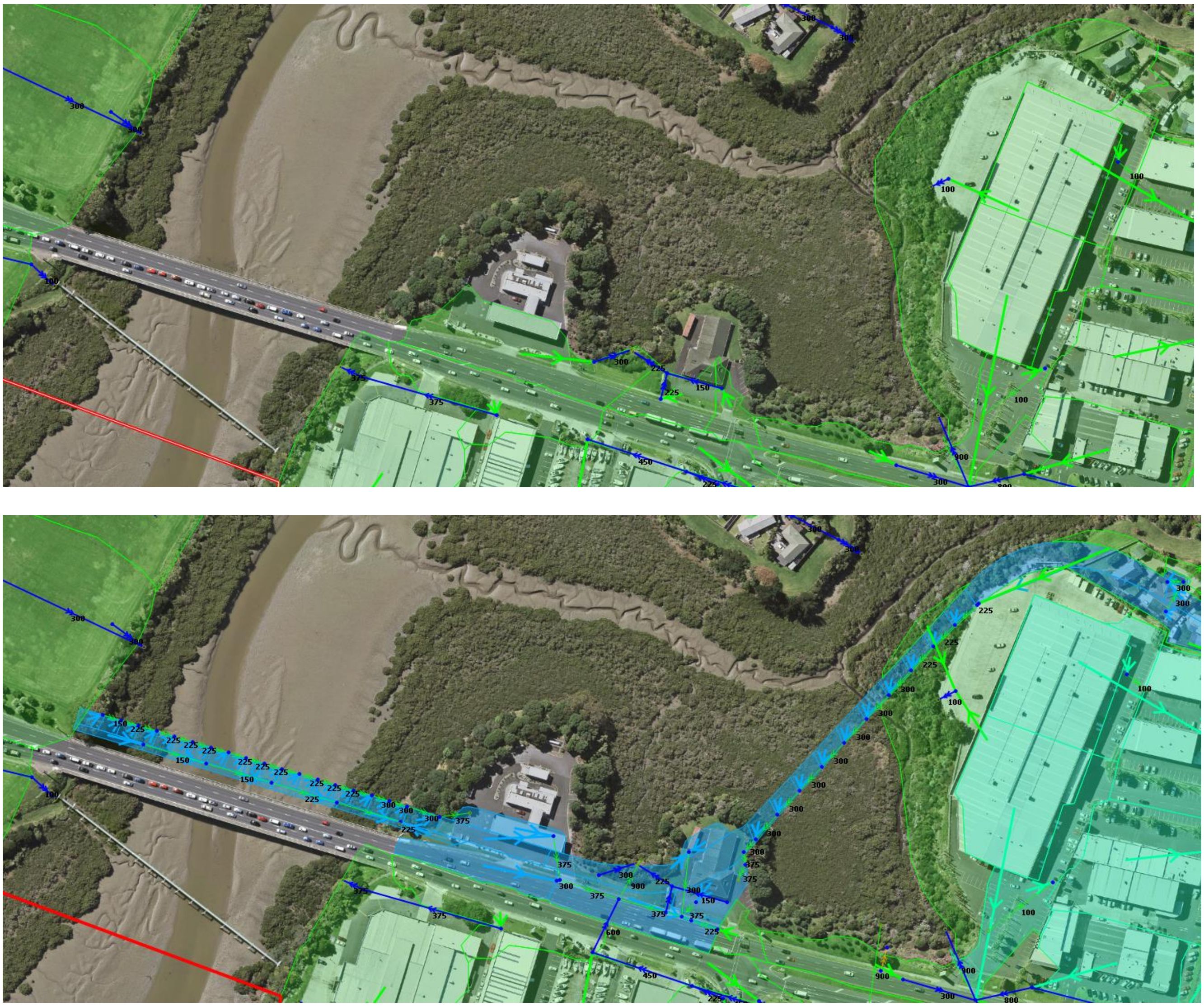

Figure 6: EB3C – EB4 base model (top image) and EB3C – EB4 design model (bottom image) with additional sub-catchments added to Ti Rakau Drive busway bridge.

3.5.6 Commercial and Residential Buildings

A site visit of existing commercial buildings in Pakuranga and Botany Town Centres was conducted on 14 May 2021. The purpose of the site visit was to identify openings in commercial buildings that could potentially allow overland flow paths through the buildings. Details from the site visit are provided are provided in Appendix 11.

Openings in the commercial buildings were represented by a 200 mm high wall allowing flow with a depth greater than 200 mm through the building opening. Buildings without openings in the flow path were represented by an impervious wall thus preventing flow through the building.

Commercial and residential building outlines were obtained from LINZ. These buildings were represented by a Manning's n value of 0.3. Aerial imagery and the site visit confirmed that some buildings around Cortina Place and Ti Rakau Drive had been removed or rebuilt with a different building footprint. Residential buildings are not represented with impervious walls.

An underground car park accessed from Reeves Road was represented with a mesh level zone. The mesh level zone was lowered to RL6.2 m which is the LiDAR level at the lowest point of the car park entrance. This would result in the car park acting like a storage area in both existing and design scenarios.

3.5.7 Manholes

The flood type of manholes surcharging in the existing model in a 100-year ARI event were changed to 2D. A 2D flood type allowed water to surcharge out of sealed manholes in the case of a manhole lid lifting off the manhole which represents reality as opposed to limiting the outflow based on perceived catchpit connections. This reduces the surcharging of manholes above lid level. Although a 2D flood type manhole will allow water to enter the stormwater network, it will allow for better representation of overland flow paths where the storm water network surcharges.

Where survey was not available for the manholes that were changed to 2D flood types, a shaft plan area of 0.16 m^2 was applied based on an assumed manhole access lid size of 450 mm. Where level surveys were not available for the amended manholes, the chamber roof level was set to 200 mm below the ground level.

3.5.8 Catchpit Q/H relationships

The existing catchpits have a Q/H relationship of a maximum inflow of 100 L/s when the head reaches 50 mm.

Design Q/H relationships were dependant on the catchpit types. Catchpit types and their relationship are provided in Table 5. Negative flows were also applied to the Q/H relationships to allow flow out of the network when surcharging occurs.

Catchpits on grade were blocked by 20% and catchpits in sag locations were blocked by 50%.

Table 5: Design Catchpit Q/H Relationships.

Catchpit Type	Maximum Inflow without Blockage (m^3/s)	Water Height Maximum Inflow Occurs At (m)
Single Catchpit	0.020	0.1
Double Catchpit	0.040	0.1
Metropit 1200 lintel	0.038	0.4
Metropit 2400 lintel	0.075	0.4
Metropit 1200	0.88	0.4
Metropit 2400	1.516	0.4
CP Megapit	0.6734	0.4
CP 1200	0.194	0.4
CP 2400	0.88	0.4
CP	0.271	0.4
Manhole with Flat Grate	1.516	2
ACO Pit (per m)	0.0048	0.4

3.5.9 Pipe Diameters

Existing pipe diameters were checked against Auckland Council Geomaps and the previous model network where they are flagged as surveyed in previous models. Pipe diameters were identified where the downstream pipe diameter was smaller than the upstream diameter. The identified downstream pipe diameters were increased to match the upstream pipe diameter where no survey information was available to confirm pipe size. This will need to be confirmed on site for the detailed design stage of the project.

3.5.10 Pipe Head loss Coefficients

Pipe head loss coefficients were reviewed along surcharging pipelines. Where the head loss coefficient was found to be significantly high (due to ICM interpolation), the coefficient was lowered to two based on the head loss equation provided in Figure 7. Reducing the head loss coefficient allows for more efficient flow through the stormwater network without additional surcharge.

$\Delta h = ku * ks * kv * (v^2/2g)$ (1)

where:

Δh = headloss

ku = user defined headloss factor

ks = surcharge ratio coefficient

kv = velocity coefficient

v = flow velocity (m/s)

g = acceleration due to gravity (m/s^2)

Figure 7: Innovyze ICM conduit head loss equation.

3.5.11 Model checks

Model checks were carried out on the results for both base and design models.

Inflow, outflow, and volume balance checks between the base and design models were carried out to ensure no unexplained differences occur (see Table 6). Total inflow is greater in the design models compared to the base models which is expected due to increased impervious area creating more runoff. Due to greater inflow and capacity to outfalls, the total outfall is also greater in the design models. Volume balance error in all models is within modelling tolerance.

Total sub-catchment area and contributing area was checked to ensure rainfall within the whole catchment was contributing to the total inflow. Additional checks were made to ensure the area between the base and design models matched to ensure there is no overlapping or gaps between the sub-catchments. Table 7 shows that total sub-catchment area and contributing area match in all models. Sub-catchment area in the EB2 – EB3R base and design models match and there is slightly more total area in the EB3C – EB4 design model than the base model due to the additional area at Ti Rakau Drive bridge.

Table 6: Inflow, outflow, and volume balance checks.

Model	Total Inflow (m^3)	Total Outflow (m^3)	Net Inflow (m^3)	Volume Balance Error (m^3)	Volume Balance Error (%)
EB2 – EB3R Base	61591298	61186936	404362	-925	0.0015
EB2 – EB3R Design	61665438	61268877	396561	-880	0.0014
EB3C – EB4 Base	22202966	21409533	793433	19419	0.0875

Model	Total Inflow (m^3)	Total Outflow (m^3)	Net Inflow (m^3)	Volume Balance Error (m^3)	Volume Balance Error (%)
EB3C – EB4 Design	22234400	21441491	792908	18751	0.0843

Table 7: Sub-catchment total and contributing area checks.

Model	Contributing Area (ha) Base	Total Area (ha) Base	Contributing Area (ha) Design	Total Area (ha) Design
EB2 – EB3R	383.6	383.6	383.6	383.6
EB3C – EB4	1158.8	1158.8	1159.3	1159.3

Predicted flood water level outside of the road corridor was checked to ensure no unexplained difference between the base and design cases occurred. In some instances, changes in water level occur between the base and design models which are not due to the design. In these instances, changes typically occur due to the meshing process of the 2D zone in the models. During the meshing process, slight changes in the triangulated ICM ground model can occur even if the underlying DEM is the same.

An example of this is shown in the long section in Figure 8 at Cindy Place shown in Figure 9. The ground levels shown in the long section graph is the ground model created by ICM, however the DEM in this location is the same. It can be seen that between 0-20 m, the ground models between the base and design match and as such the water levels match due to the flow being the same. However, variations in the ground model occur after 20 m causing variations in water level. This causes adjacent increases and decreases in water level between the base and design at Cindy Place where it would be expected to see a constant increase or decrease in water level if there was an impact from the design.

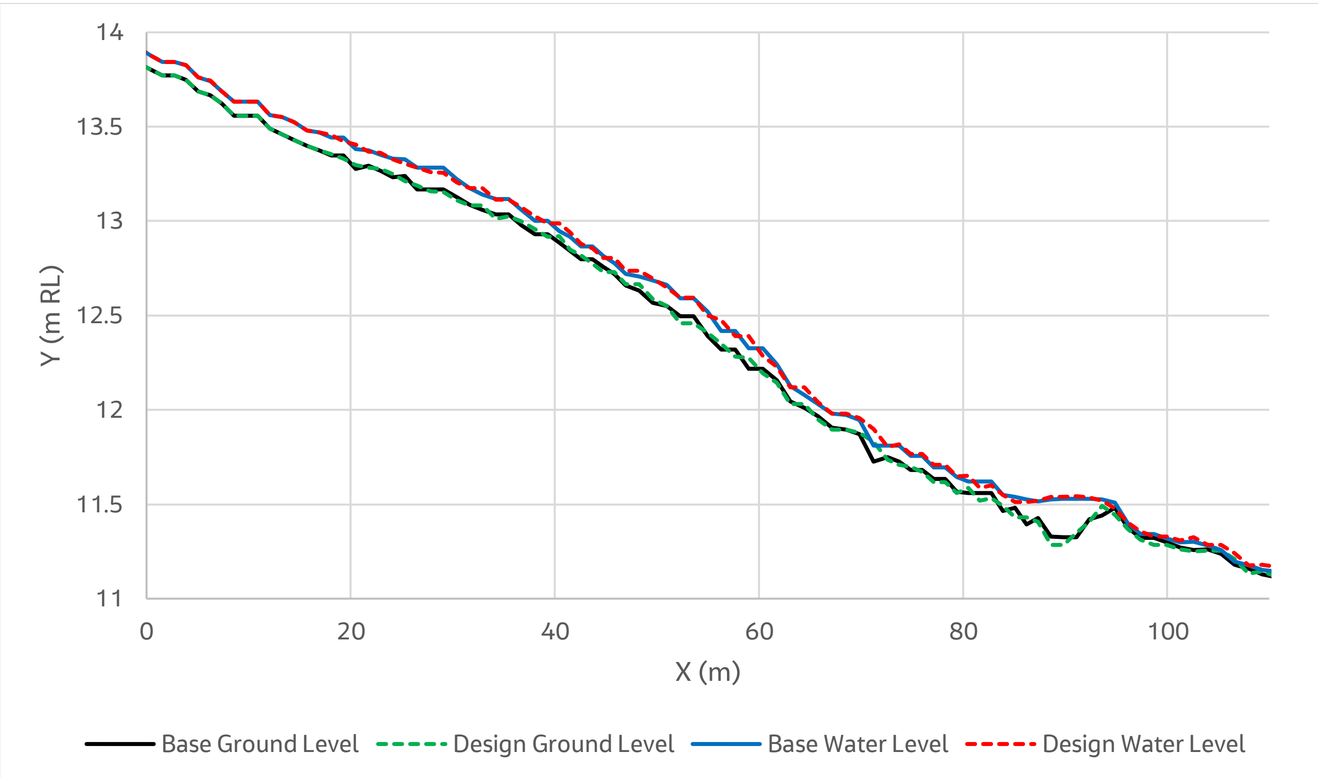

Figure 8: Ground level and water level long section at Cindy Place shown in Figure 9.

Tamaki and EB base case results were compared to ensure no unexplained differences occurred. The Tamaki model used 2013 LiDAR compared to the EB models using 2016 LiDAR. In addition to this, the Tamaki model used a cell size between 2-4 m compared to the cell size of 0.25 m used in the EB model. This creates significantly different results in some areas but are expected due to the updates made in the EB models.

Due to the difference in vertical datums, a model wide comparison of water levels was not suitable. However, a water depth comparison was undertaken which shows variations in depth between the two models generally to be within +/-500 mm. Several areas were checked in detail to ascertain the cause in depth difference. An example of the depth difference is provided in Figure 10 to the south of Ti Rakau Park which refers to cross section data provided in Figure 11.

The depth difference map shows that depth over Ti Rakau Drive has increased. A cross section comparing the base model ground models and water levels (converted to match vertical datum) is provided to explain the cause in increased depth.

The Tamaki ground model uses a larger cell size which causes the highest and lowest points in a single cell to be averaged across the cell. This causes detail such as curb heights and gullies to be lost which is represented better in the EB models due to the relatively small cell size. The difference in ground models means the water level in the Tamaki model must reach RL8.7 m to overtop the downstream road curb. In comparison, the water level in the EB2 – EB3R model must reach RL8.8 m to overtop the downstream road curb. This causes additional water to back up in the road before overtopping can occur in the EB2 – EB3R model despite a similar flow rate compared to the Tamaki model. The difference in ground model elevations between the base models is similar to the difference in depths where water overtops the downstream kerb.

Figure 9: Long section referred to in Figure 8.

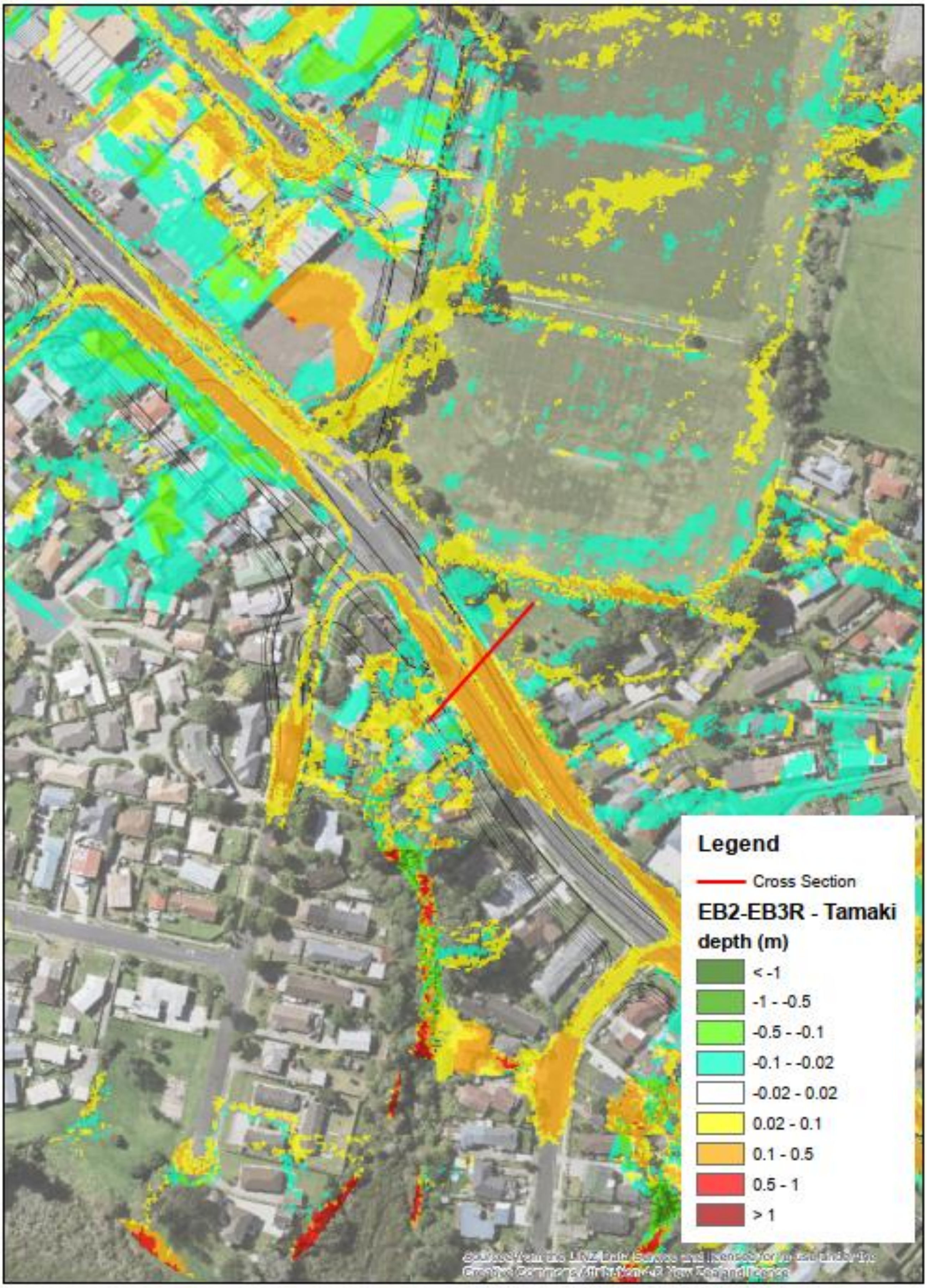

Figure 10: EB2-EB3R - Tamaki depth difference at Ti Rakau Park.

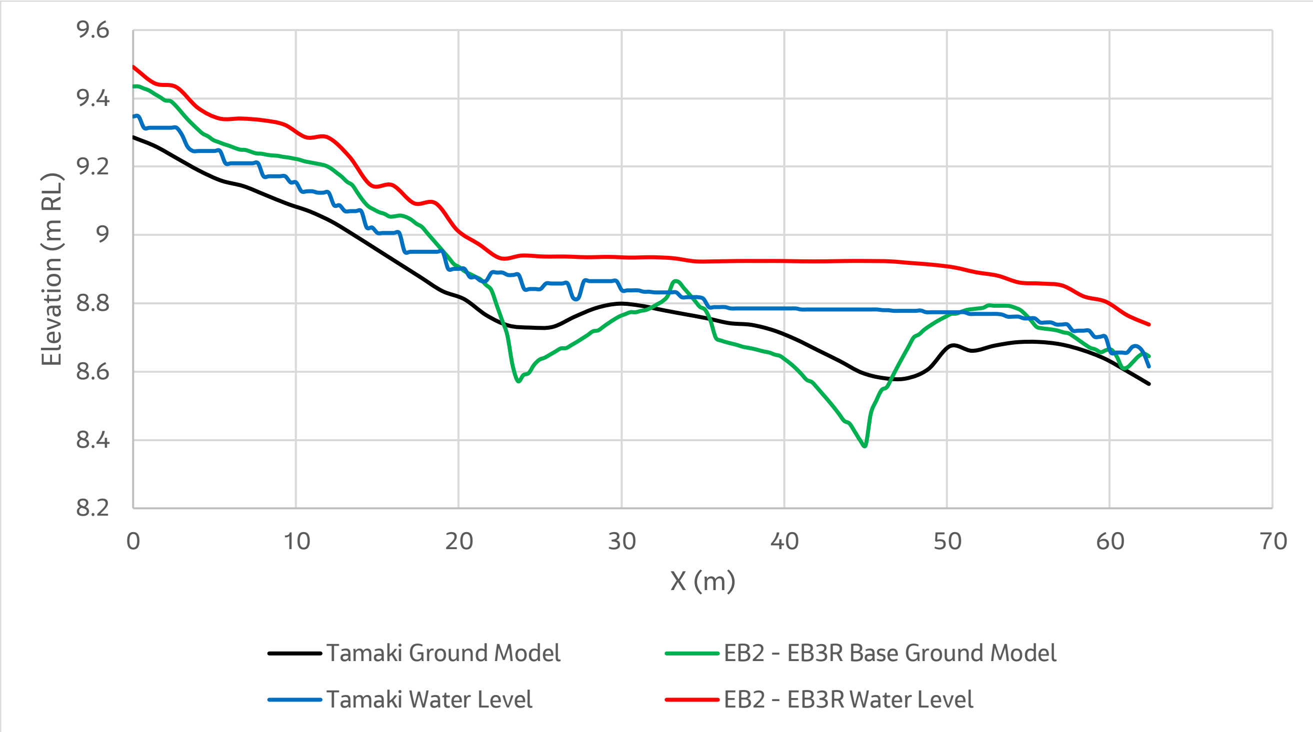

Figure 11: Cross section of Tamaki and EB2-EB3R ground models and water levels.

3.5.12 William Roberts Road Consenting

A temporary connection crossing Ti Rakau Drive from WRR was modelled for consenting purposes.

The EB2 – EB3R design model was amended to create a scenario with the WRR geometrics and stormwater network. The proposed design stormwater network crossing Ti Rakau Drive was removed and a temporary connection from the WRR design network was made into the existing 900 mm pipe crossing (SAP ID 2000693842), see Figure 12. The ground model at the Ti Rakau Drive pipe crossing was reverted back to existing levels. Design geometrics and stormwater network with no interaction with WRR was not removed from the model.