Northern Corridor Improvements

Assessment of Stormwater Management

Project No: 250310
Document Ref: NCI-3PRE-2ENV-RPT-0029
Revision: 2

12 December 2016

NZ TRANSPORT AGENCY
WAKA KOTAHI

aurecon

KensingtonSwan
LAWYERS

Quality Assurance Statement	
Prepared by:	David Hughes / Matthew Yu / Tallulah Kaegi (Aurecon)
Reviewed by:	Don Mackintosh (Aurecon)
NZTA Reviewer:	David Greig
Approved for issue by Aurecon:	Jon Hind
Approved for use by NZTA:	Kenny See

Executive summary

This report discusses the stormwater management assessment undertaken, and the desired outcomes for the Project with respect to managing stormwater runoff from existing and new impervious areas over the Project. These outcomes include:

- Minimise flooding effects to upstream and downstream environments within the Oteha Valley Stream and Lucas Creek stormwater catchments through attenuation of peak flows;
- Minimise effects of additional or extension of existing High Use Road (HUR) pavement areas through treatment of stormwater in accordance with Auckland Council (AC) Standards;
- Minimise effects associated with stream channel erosion downstream of the Project through detention of stormwater runoff;
- Minimise long-term maintenance and operational requirements of the proposed stormwater management system; and
- Take into account safety issues in the construction, maintenance and operational phases of the Project.

The water quality treatment and quantity control devices proposed for the Project have been designed using a comprehensive best practicable option (BPO) approach.

Auckland Unitary Plan

The proposed stormwater management measures have been developed in accordance with the requirements of the Auckland Unitary Plan Operative in Part, 15 November 2016 (AUP).

Design Standards

The stormwater management measures for the Project are based on the following key Auckland Council and the NZ Transport Agency regulatory guides and standards:

- Auckland Council – TP10 (as referenced in the AUP);
- Auckland Council – TR2013/035;
- Auckland Council – Stormwater Code of Practice (October 2015);
- Auckland Transport – Chapter 17 Road Drainage (2013); and
- The NZ Transport Agency Stormwater Treatment Standard for State Highway Infrastructure (2010).

Potential Stormwater Surface Water Effects

The following impacts are identified as the potential surface water impacts that may result from the Project on the receiving environment:

- Adverse impacts on receiving water quality due to discharges of motorway runoff;
- Increased peak flood levels downstream of motorway runoff discharge locations;

- Increased peak flood levels upstream of motorway associated with changes to cross drainage infrastructure (culverts) and reduction of storage at ponded locations;
- Increased flooding impacts associated with changes to overland flow paths adjacent to the motorway;
- Cumulative impacts on the hydrologic regime (downstream flow) in receiving environments (in particular the hydrograph recession curve) associated with the proposed detention and attenuation of treated water, and the diversion of flows between sub-catchments;
- Increased erosion and changes to stream geomorphology in receiving environments associated with motorway discharges;
- Restriction of the passage of aquatic species associated with changes to cross drainage infrastructure (culverts); and
- Increased water temperature downstream of motorway discharges associated with additional impervious areas and detention of water in proposed wetlands and ponds.

Stormwater Management Measures Proposed

The proposed stormwater management measures for the Project have targeted mitigation and avoidance of the above identified potential effects.

The management of stormwater throughout the Project is primarily achieved by a treatment train approach through the use of piped networks with sumps, planted conveyance and treatment swales, constructed wetlands, dry ponds and proprietary devices. Treatment, detention and attenuation of stormwater runoff has been proposed in accordance with AC standards to varying levels to minimise adverse effects caused by runoff from existing and new impervious surfaces over the Project.

Retention through infiltration has been found to be largely unachievable on this Project due to local soil conditions having low permeability, a relatively high groundwater level and the lack of opportunities to re-use water on site. However the use of longitudinal planted swales and stormwater wetlands to capture and manage runoff from impervious areas achieve an element of retention through infiltration, and plant uptake in some areas.

Peak flow attenuation has been provided for all motorway sub-catchments to varying degrees, to minimise the effects of flooding downstream. In sub-catchments where other downstream properties have been identified by information provided by AC as being at risk of flooding, peak flow attenuation for events up to the 10-year ARI has been provided. In sub-catchments where downstream buildings are at risk of flooding, peak flow attenuation for events up to the 100-year ARI has been provided.

In summary, the proposed stormwater management scheme for the Project includes:

- Improving the current situation where 52% of existing motorway HUR impervious area is treated, to 99% of total proposed (existing and new) motorway HUR impervious areas treated to Auckland Council standards (75% TSS removal on a long-term average basis in accordance with TP10);
- Providing provision for attenuation of peak flows for various storm events to manage flood impact of upstream and downstream environments;
- Using wetlands, proprietary treatment devices and dry ponds for providing stormwater treatment, detention and attenuation for the Project;
- Using wetlands as the primary type of stormwater management device, which with appropriate planting can adequately control discharge water temperature;
- Providing detention of stormwater runoff in all sub-catchments, and provision for erosion protection measures (rip-rap aprons and basins) at all new and modified stormwater outlets to manage stream channel erosion downstream;
- Using planted swales where practical to provide conveyance of stormwater flows and informal pre-treatment; and

- Using existing stormwater assets including piped systems, swales, treatment devices, etc. is proposed where possible.

Fish passage is not a consideration, as there are no upstream native fish habitat (the catchment is fully urbanised and culverted); there are significant barriers downstream, including vertical manholes; and there is currently only very poor quality habitat for native fish (exposed, concrete drains).

Assessment of Effects

As a result of the stormwater management controls proposed for the Project, the assessment shows that predicted flood levels will decrease for a number of properties previously identified on flood maps and reporting as being at risk of flooding.

The proposed stormwater quantity management will reduce flooding in most areas. In summary, the effects are as follows:

- Significant reduction (300mm to 460mm) in peak flood levels at Meadowood Reserve, identified by AC as a flood prone location with regards to flooding impacting on a nearby kindergarten;
- Up to 80mm increase in peak flood levels for the 100 year ARI event in Alexandra Stream downstream of UHH crossing. The increases do not extend beyond the Paul Matthews Road Bridge and that there are no buildings identified as at risk of above floor flooding (floor within 500mm of the 100 year ARI MPD flood level) in this location;
- Up to 70mm increase in peak flood level for the 100 year ARI event in Alexandra Stream immediately upstream of UHH crossing. The increase does not extend beyond the Barbados Drive Bridge and 500mm of freeboard for habitable floor levels will remain at the property at 125 Unsworth Drive; and
- There is a small increase (60mm in the 100 year ARI event) in peak water level within the shared underpass at the UHH/Alexandra Stream crossing. The increase in flooding does not impact the usability of the underpass, as it is already significantly under water in the current situation (2.4m depth of water in the 100 year ARI event within the underpass).

The stormwater quantity mitigation devices (including proposed flow attenuation devices, cutoff drains, culvert works, erosion protection at outfalls, etc.) will appropriately mitigate the flooding effects of the Project on the wider catchment.

The potential water quality effects and the effects on freshwater ecology are addressed in the Assessment of Surface Water Quality Effects and Assessment of Freshwater Ecological Effects.

Contents

Appendices

Figures

Tables

Glossary of Abbreviations

Item	Description
AC	Auckland Council
AEP	Annual Exceedance Probability
AMA	Auckland Motorway Alliance
ARC	Auckland Regional Council
ARI	Average Recurrence Interval
AT	Auckland Transport
AUP	Auckland Unitary Plan Operative in Part, 15 November 2016
BPO	Best Practicable Option
CEMP	Construction Environmental Management Plan
CH	Motorway Chainage – Refer to the stormwater drainage drawings for chainages
CoP	Code of Practice
ED	Existing Development
HUR	High Use Roads
MfE	Ministry for the Environment
MPD	Maximum Probable Development
NDC	Network Discharge Consent
NSCC	North Shore City Council
NZ Transport Agency	New Zealand Transport Agency
OF	Outfall
PAUP	Proposed Auckland Unitary Plan, Decisions Version, 19 August 2016
PFA	Peak flow attenuation
PM2AH	Paul Matthews Road to Albany Highway
Q_{100}	Design flow during an ARI 100y rainfall event
RFHA	Rapid Flood Hazard Assessment
RWWTP	Rosedale Wastewater Treatment Plant
S2R	Spencer Road to Greville Road
SH1	State Highway 1
SH18	State Highway 18
SMAF	Stormwater management areas for flow control
SUP	Shared-use path
TP10	Auckland Council Technical Publication No. 10 (2003)
TP108	Auckland Council Technical Publication No. 108 (1999)
TR2013/035	Auckland Council Technical Report 2013/035 (2013)
TSMS	Total Stormwater Management System
TSS	Total Suspended Solids
UHH	Upper Harbour Highway

Item	Description
UHH2G	Upper Harbour Highway to Greville Road Upgrade
WL_{100}	Modelled water level (excluding freeboard) during an ARI 100y rainfall event
WQ	Water quality
WQV	Water quality volume
Watercare	Watercare Services Limited

Terms and Definitions

Term	Definition
75% TSS Removal	This has the meaning of 75% TSS removal on a long-term average basis in accordance with TP10.
Alignment	The route or position of the proposed motorway.
Artificial watercourse	Has the same meaning as defined in Chapter J of the AUP: Constructed watercourses that contain no natural portions from their confluence with a river or stream to their headwaters.
Best Practicable Option	Defined in Section 2 of the RMA.
CCTV	Condition inspection of existing pipes undertaken using a remote controlled vehicle equipped with a camera. Survey is undertaken and condition is scored in accordance with New Zealand Pipe Inspection Manual Third Edition (NZWWA, 2006).
CS-VUE	CS-VUE is a web based software database containing Resource Consent and legal information. CS-VUE has been used extensively on the Project to obtain and assess existing consent information relating to stormwater management conditions and compliance requirements.
Extended Detention	Runoff from a rainfall event of 34.5 mm stored and released over a 24 hour period to minimise potential for stream channel erosion. This has been replaced by detention in the Auckland Unitary Plan.
Detention	Detention (temporary storage) with a drain down period of 24 hours for the difference between the pre-development and post-development runoff volumes from the 95^{th} and 90^{th} percentile (for SMAF1 and SMAF2 respectively), 24 hour rainfall event minus the retention volume for all impervious areas.
Discharge	An activity that results in a contaminant being emitted deposited or allowed to escape.
Diversion of Stormwater	Redirecting stormwater from its existing course of flow; causing it to flow by a different route.
Do Minimum	Term used in the context of a comparison between the effects of a project and the effects that would occur if the project was not undertaken (i.e. for the comparative evaluation of the effects 'with and without' the project).
Grade Separated Interchange	The layout of roads where one road crosses over/under the other at a different height.
HEC-HMS	The Hydrologic Modelling System used to simulate and assess hydrologic processes flood risk for the Project.
High Use Roads	A road, motorway or State Highway that carries more than 5000 vehicles per day, excluding cycle lanes, footpaths and ancillary areas that do not receive stormwater runoff from the road carriageway.
Hydrology	The branch of science concerned with the properties of the earth's water.
HY-8	The Culvert Hydraulic Analysis Program used to assess culvert capacity for the Project.
Overland Flow Path	The natural flow path of stormwater over the ground.
Peak Flow Attenuation	Reduction of peak flows from extreme rainfall events (2-year ARI, 10-year ARI and 100-year ARI) to pre-development levels, typically achieved through the use of wetlands and dry ponds.
Pedestrian/Cycleway	A dedicated facility for the shared-use of pedestrians and cyclists.
Pier	Vertical support structure for a bridge.

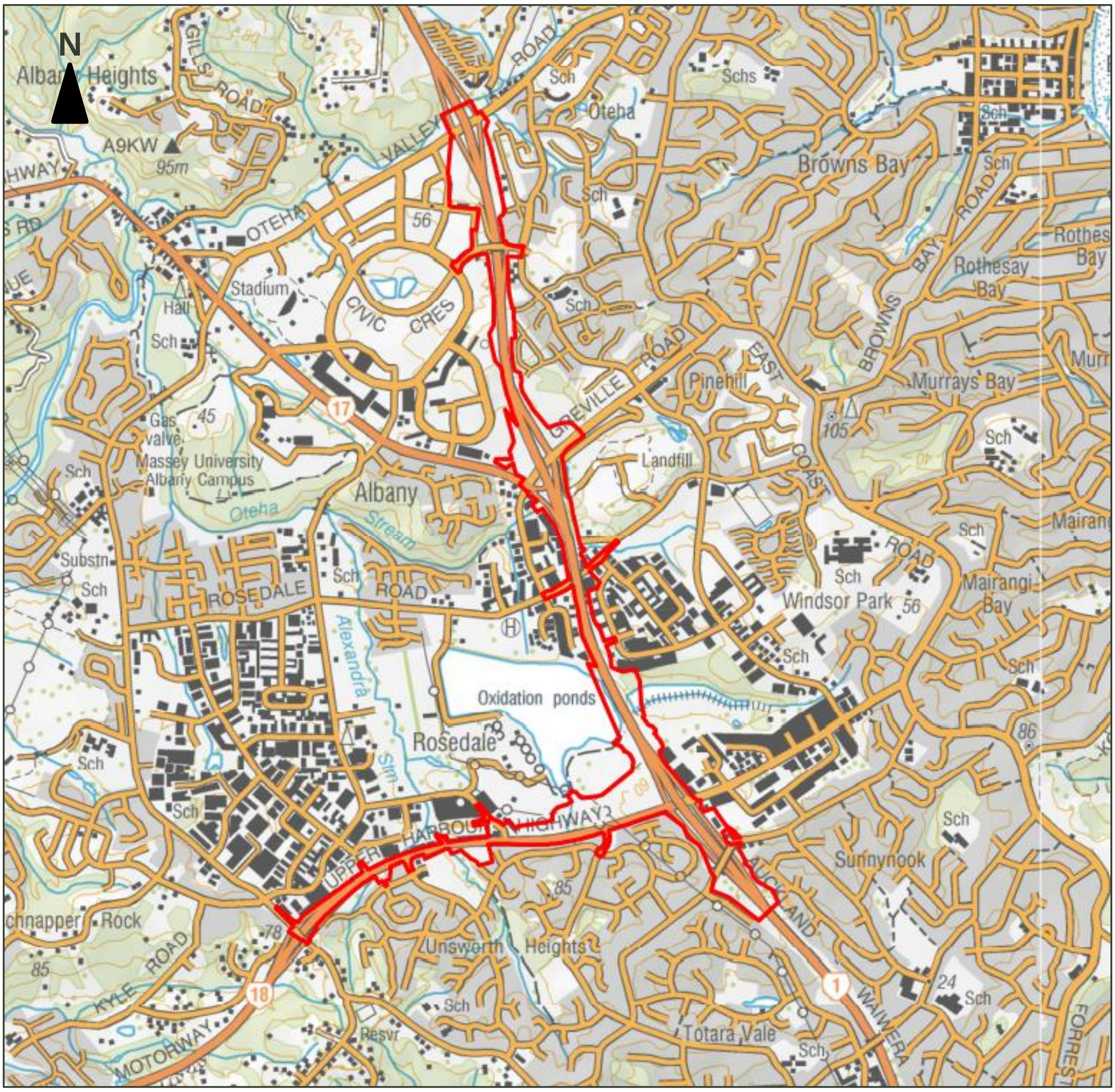
Term	Definition
Project	Refers to the Northern Corridor Improvements Project including the extension to the Northern Busway and proposed Shared Use Pathway.
Sediment Control	Capturing sediment that has been eroded and entrained in overland flow before it enters the receiving environment.

1 Description of Project

1.1 Project Background

The Northern Corridor Improvements Project (the Project) is an accelerated project. The Project area covers the area of State Highway 18 (SH18) between Albany Highway and Constellation Drive, and State Highway 1 (SH1) between the Upper Harbour Highway (UHH) interchange to just beyond the Oteha Valley Road Interchange as indicated on **Figure 1** below and set out in the suite of plans provided in **Volume 5**.

Figure 1 Extent of Project Area



Source: Base Map from LINZ

The Project proposes to upgrade the existing State highways within the Project area. In summary, the key elements of the Project are as follows:

- Northern and Western Motorway Interchange connections – SH1/SH18;
- State highway capacity and safety improvements;
- Northern Busway extension from Constellation Bus Station and connection to Albany Bus Station;
- Reconfiguration of Constellation Bus Station converting it from a terminus station to a dual direction station;
- Shared Use Path (SUP) provision along existing SH1 and SH18 routes for the full extent of the Project corridor:
  - Constellation Station to Oteha Valley Road;
  - Constellation Drive to Albany Highway; and
  - Intermediate linkages to local network.

A full description of the Project, including its components and construction, is contained in the Assessment of Environmental Effects (AEE) for the Project (**Volume 2**).

1.2 Purpose of this Report

This report is one of a suite of technical reports that has been prepared to inform the AEE.

The particular focus of this report is to describe the stormwater management measures proposed for the Project and provide an assessment of the effects that the Project will have in relation to stormwater quantity and flooding. Other effects relating to stormwater discharges are discussed in further detail in reports summarised in **Table 1**.

Table 1 Reports addressing other effects relating to stormwater

Report Name	Report Reference	Topic
Assessment of Construction Water Management	NCI-3PRE-2ENV-RPT-0023 (Volume 3 – Technical Assessment 4)	This report addresses the potential stormwater management effects during construction.
Assessment of Freshwater Ecological Effects	NCI-3PRE-2ENV-RPT-0024 (Volume 3 – Technical Assessment 5)	The Assessment of Freshwater Ecological Effects outlines the receiving freshwater environment including habitat, fish passage and temperature. The information in the report has been used to inform the best practicable option (BPO) analysis and the mitigation measures proposed.
Assessment of Surface Water Quality Effects	NCI-3PRE-2ENV-RPT-0039 (Volume 3 – Technical Assessment 12)	This report contains information about the baseline water quality and flow monitoring in the Oteha Valley and Lucas Creek catchments, and an assessment of the water quality effects resulting from the Project.
Design and Constructability Report	NCI-3PRE-3DES-RPT-0049 (Volume 3 – Technical Assessment 15)	The Design and Constructability Report contains information about the likely construction sequencing of stormwater assets.

2 Existing Environment

2.1 Overview

This section provides a description of the existing environment, including an assessment of the existing catchments, the stormwater management controls that are currently in place within the Project area and the performance of those existing treatment systems. It is to be read in conjunction with the Stormwater Layout Plans in **Appendix A**. **Figure 2** also provides an overview of the location of affected existing stormwater assets across the Project area.

The locations of the drainage features are described using motorway chainages (CH). The chainage system increases from north to south on SH1, and from east to west on SH18.

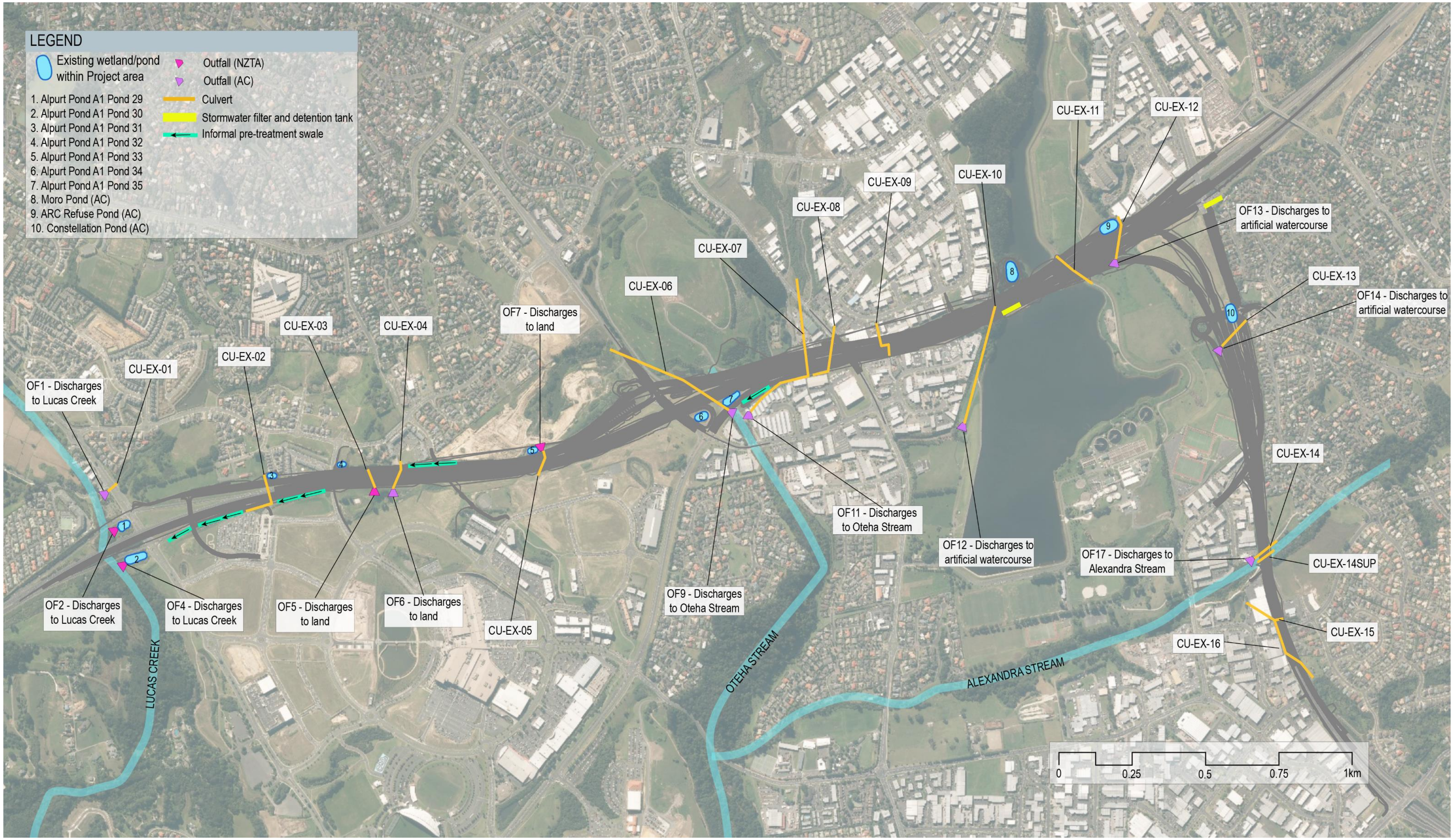
2.2 Existing Records

Information from a wide variety of sources has been reviewed to establish an understanding of how stormwater from the existing motorway environment is managed including:

- Documents relating to previous motorway projects within the Project area;
- Reports regarding the management of stormwater around Ponds 1 and 2; and
- The catchment management plans for the relevant catchments.

The material reviewed is listed in full in **Appendix C1**. Photos showing various sites throughout the Project area also provided in **Appendix C2**.

Figure 2 Existing Stormwater Devices and Outfall Locations



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2.3 Stormwater Catchments

The Project falls within the Oteha Valley and Lucas Creek catchments. SH1 and SH18 intersect with, and ultimately discharge to, the following waterways:

- Lucas Creek;
- Oteha Stream; and
- Alexandra Stream (a tributary of Oteha Stream).

The boundary between the Lucas Creek and Oteha Valley catchments is located at Spencer Road – to the north is Lucas Creek and to the south is the Oteha Valley catchment. The Oteha Valley and Lucas Creek catchments are shown below in **Figure 3** and **Figure 4** respectively.

The catchment area of Oteha Valley is approximately 1,310 ha to the confluence of Lucas Creek, some 4km downstream of SH1. Oteha Valley includes Oteha Stream and its major tributary – Alexandra Stream, with a catchment area of 270 ha. The Oteha Valley catchment includes the Rosedale Ponds (part of the Rosedale Wastewater Treatment Plant (RWWTP)), the Massey University Campus and the Rosedale Closed Landfill. The catchment contains large sections of both residential and commercial / industrial land uses, with large portions of the upstream catchment piped.

As set out in the Assessment of Freshwater Ecological Effects (**Technical Assessment 5**), the upper Oteha Stream within Tawa Reserve forms a stabilised steep sided watercourse. The area of the watercourse within the Project area includes the culvert, culvert apron, the scour pool and stream immediately below the pool. The aquatic ecological values of the watercourse within the Project area are low.

Alexandra Stream within the Project area forms a thickly vegetated watercourse with the potential for moderate to high volume flows, evident from flood debris on the bank and the size of the catchment. The aquatic ecology values are classified as 'moderate' (refer Assessment of Freshwater Ecological Effects Report).

The area of the Lucas Creek catchment is approximately 625ha to the confluence with Oteha Stream, some 2.5km downstream of SH1. The upstream catchment land use is mostly residential, and downstream of the SH1 crossing the catchment is a mix of rural and residential, and contains the Massey University Campus and the Albany Bus Station.

As set out in the Assessment of Freshwater Ecological Effects, Lucas Creek retains some ecological values despite land use changes that have occurred (i.e. urbanisation of large parts of the catchment, culverting many of the tributaries and bridging of the watercourse and retention works for SH1). This section of the stream scored well for its water quality, namely the high amount of shading maintaining good temperature control, and retention of particles and organic matter, but poorly for biodiversity (fish and macroinvertebrates) and access to the floodplain. The aquatic ecology values in this stream are classified as 'moderate'.

All three streams receive stormwater runoff from the existing motorway with varying levels of treatment as outlined in **Section 2.4**.

Table 2 below summarises the downstream conditions of the main streams and creeks that currently receive stormwater runoff from SH1 and S18 within the Project area. For details of the water quality of these watercourses, refer to the Assessment of Surface Water Quality Effects (**Technical Assessment 12**).

Table 2 Existing stream characteristics and downstream issues

Stream Name	Downstream Flooding	Downstream Erosion
Lucas Creek	None identified from catchment stormwater report supplied by Auckland Council (AC) on Lucas Creek. The main areas affected by flooding in the Lucas Creek catchment are located on tributaries (not affected by proposed works) discharging into the lower reaches of Lucas Creek (NSCC, 2009).	The Lucas Creek Catchment Management Plan identifies severe erosion in the lower half of the main channel (NSCC, 2010). The upper half of the main channel has only slight bank erosion in areas with little riparian vegetation.
Oteha Stream	Downstream flooding noted for some properties for the 100 year ARI flood event along the main Oteha Stream floodplain.	No known issues or concerns were raised by AC during consultation on the stormwater management measures proposed for this sub-catchment. The Oteha Valley Catchment Management Plan (NSCC, 2001) identifies that the stream is gradually re-sizing to post development flows.
Alexandra Stream	None noted from Oteha Valley Catchment Stormwater Modelling – Model Build and System Performance Report (2013) supplied by AC.	Erosion in Alexandra Stream was noted by AC during consultation on the stormwater management measures proposed for this sub-catchment.

Figure 3 Oteha Valley Catchment Plan

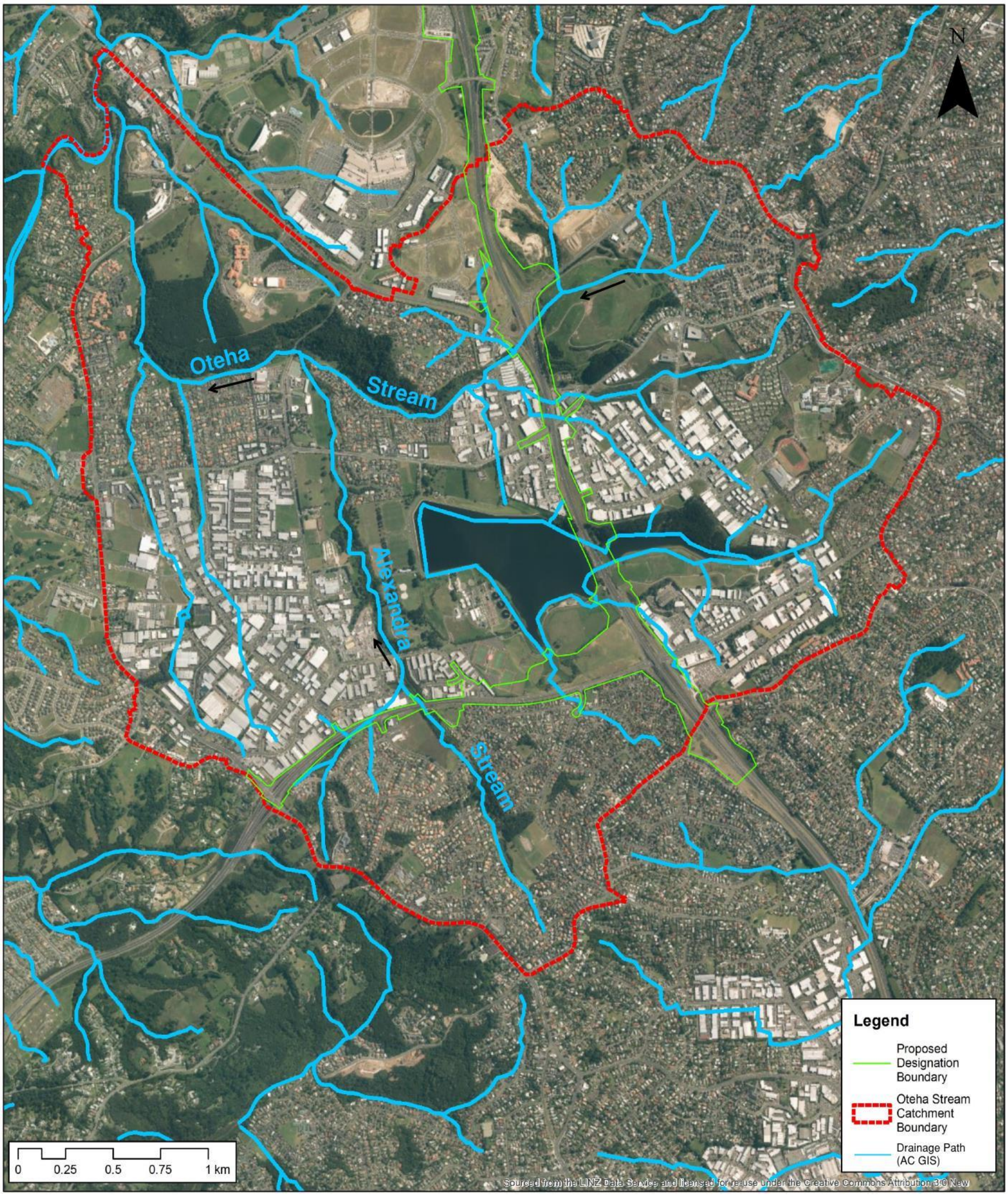

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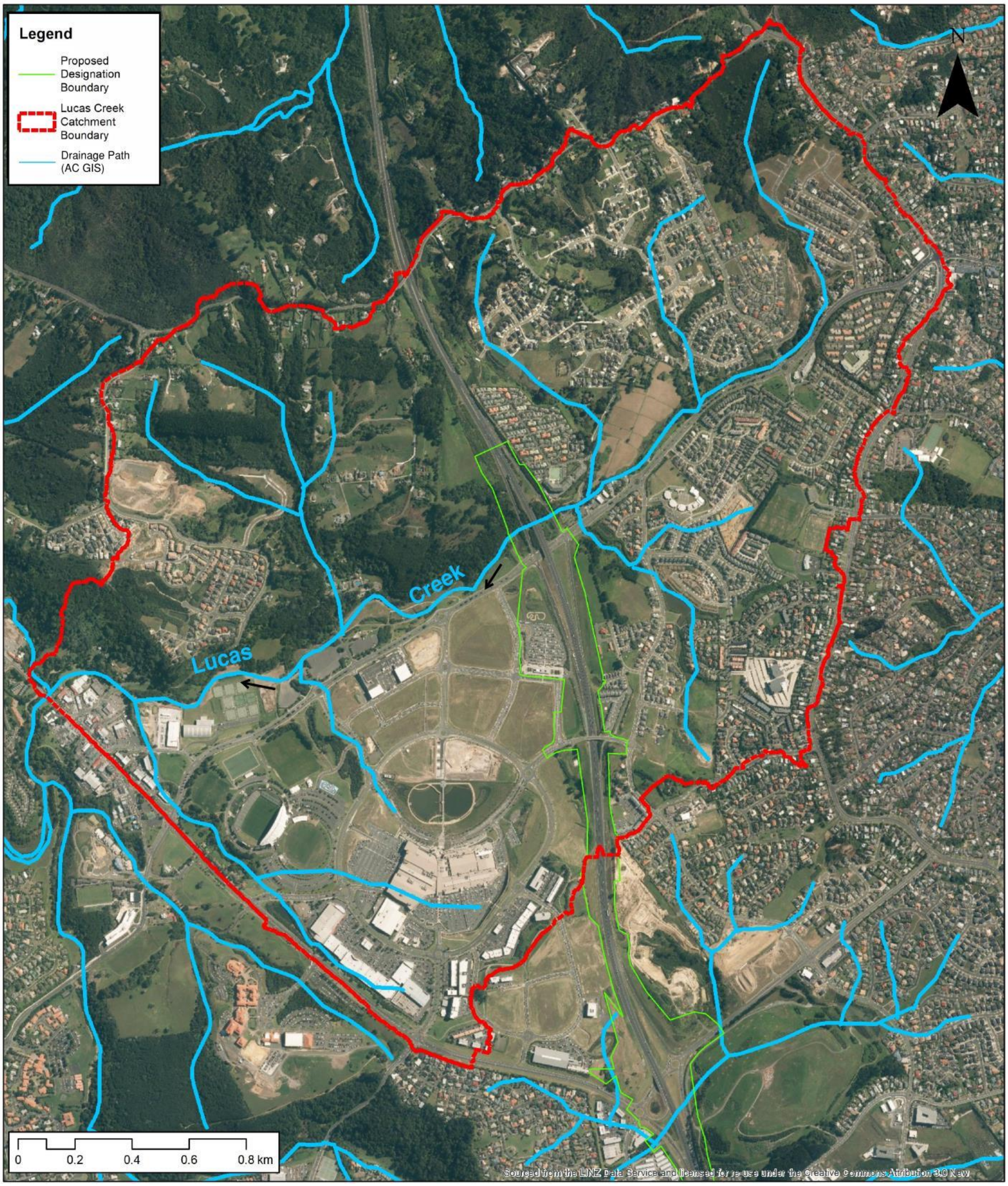
Figure 4 **Lucas Creek Catchment Plan**



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2.4 Existing Stormwater Management

Over the past 30 years the NZ Transport Agency has constructed numerous stormwater treatment and attenuation devices as part of motorway upgrade works within the Project area. These devices are shown in **Figure 2**, and were designed and constructed to provide varying levels of quality and quantity management of stormwater runoff as follows:

- North of Rosedale Road, the existing ponds were constructed as part of the Alpurt A1 project to provide limited stormwater treatment and attenuation of runoff from existing pavement areas. These ponds all discharge to Lucas Creek, Albany Lakes Reserve and Oteha Stream;
- South of Rosedale Road on SH1, there are two StormFilters which were installed as part of the Upper Harbour Highway to Greville Upgrade (UHH2G) and Traffic Demand Management (ramp signalling) projects. The StormFilter treatment installed as part of the UHH2G project also included a separate tank with 38m^3 of storage to provide extended detention of stormwater. These discharge to the existing AC pipe reticulation network, then discharges to the modified watercourse north of Watercare Services Limited's (Watercare) Pond 1 via Outfall (OF) 12;
- On SH18, there is no existing stormwater treatment or attenuation of runoff from existing pavement areas prior to discharge into Alexandra Stream; and
- Stormwater runoff from the part of the Constellation Bus Station to be upgraded as part of the works is currently treated and managed by an engineered grassed swales and detention tank on the western side of the station. This system discharges to the AC pipe reticulation network.

The existing motorway stormwater management devices noted above are predominantly serviced by piped stormwater systems of varying age and condition within the existing carriageway, which are shown on the Stormwater Layout Plans in **Appendix A**.

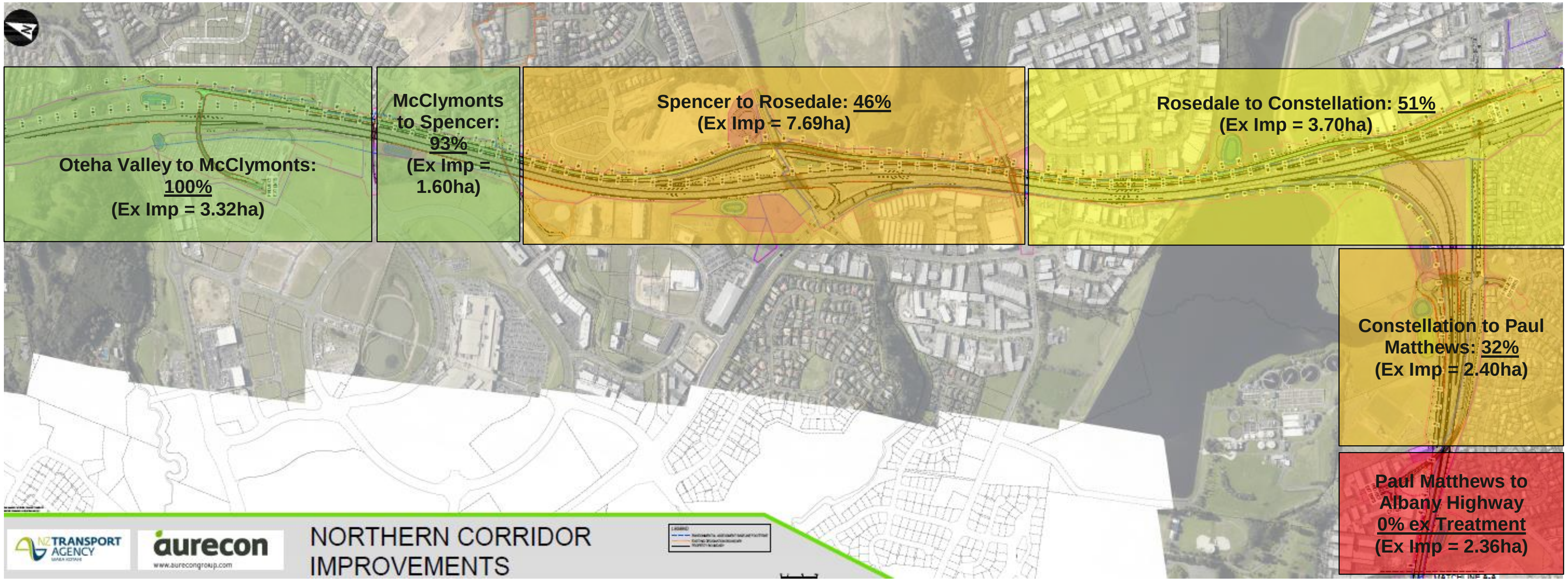
2.4.1 Existing Motorway Treatment Performance by Sub-Catchment

The performance of the existing stormwater management devices within the Project area has been assessed using a combination of survey, historic project resource consent applications and reports, design / as-built drawings and existing consent conditions, to understand how the current system is operating. The material reviewed is listed in full in **Appendix C1**.

This assessment also involved calculating existing pavement areas over the Project area using LiDAR and physical survey, and aerial photography flown in June 2016. The existing stormwater ponds affected by the works were also surveyed to confirm their size and capacity.

The percentage of existing impervious area treated to 75% total suspended solids (TSS) removal standard (in accordance with AC's Technical Publication 10 (TP10)) for each sub-catchment of the Project area is shown in **Figure 5**. Impervious areas which are treated to less than 75% TSS removal as per TP10 are not included in the percentages in **Figure 5**. Treatment efficiencies were calculated based on the total catchment areas discharging to each pond (all impervious and pervious areas). Further detail relating to the operation and performance of the existing devices within each sub-catchment is provided in **Appendix D**.

Figure 5 Existing percentage of motorway impervious areas that are treated to 75% TSS removal standard (TP10)



2.4.2 Existing Motorway Stormwater Management Devices

Table 3 below provides a summary of all existing stormwater ponds within the Project area that treat stormwater runoff from the existing motorway. **Figure 2** shows the location of these devices. There are no existing treatment devices located within the Paul Mathews to Albany Highway sub-catchment of the Project. Stormwater within this area discharges straight to the Alexandra Stream without any treatment.

Table 3 Existing stormwater management devices[1]

Treatment Device	Water Quality Volume (m^3)	Live volume (m^3)	Existing impervious area treated to 75% TSS removal (ha)	Discharge point	Source of information used to assess existing treatment device
State Highway 1 Alpurt A1 Pond 30	295	1670	2.62	Lucas Creek	Alpurt A1 O&M Manual (July 2001)
State Highway 1 Alpurt A1 Pond 31	410	545	0.70	Lucas Creek	Survey (July 2016)
State Highway 1 Alpurt A1 Pond 32	325	480	1.48	Albany Lakes Reserve	Survey (July 2016)
State Highway 1 Alpurt A1 Pond 33	115	325	0.80	Oteha Stream	Survey (July 2016)
State Highway 1 Alpurt A1 Pond 34	300	1100	2.72	Oteha Stream	Survey (July 2016)
State Highway 1 Alpurt A1 Pond 35	230	770	0.00 (3.88ha treated to approx. 55% TSS removal)	Oteha Stream	Survey (July 2016)
State Highway 1 UHH2G – StormFilter (AC approved type)	N/A	38	1.89	AC network	UHH2G Design Report (June 2013) and As-Built Drainage Plans (August 2015)
State Highway 1 TDM – UHH NB off-ramp StormFilter (AC approved type)	N/A	0	0.77	AC network	TDM Consent Condition (October 2008)

[1] The information shown in Table 3 has been sourced from the following documents:

- Alpurt A1 O&M Manual (July 2001) – State Highway 1: Albany to Puhoi Realignment, Sectors A & B1 Stormwater Treatment Devices, Maintenance and Operation Guidelines, Report No. 010702, dated July 2001;
- UHH2G As-Built Drainage Plans Sheets 1 to 11, 3817032-C-191 to 201 (Rev AB-1), dated 4 August 2015
- UHH2G Design Report (June 2013) – State Highway 1 Upper Harbour Highway to Greville Northbound Improvements Design Report, dated 21 June 2013; and
- TDM Consent Condition (October 2008) – Resource Consent No. 36282, to authorise the diversion and discharge of stormwater in accordance with section 14 and 15 of the Resource Management Act 1991, dated October 2008.

2.4.3 Existing Stormwater Outfalls

The existing treatment devices either discharge to existing outfalls or AC's stormwater network. As noted above, stormwater from the Paul Mathews to Albany Highway sub-catchment discharges straight to the Alexandra Stream without any treatment.

The locations of the existing outfalls are shown on **Figure 2** (and in more detail on the Stormwater Layout Plans in **Appendix A**). The locations of where stormwater discharges enter AC's stormwater network are also shown on **Figure 2**.

Table 4 provides a summary of the relevant resource consents and conditions relating to stormwater management for the existing motorway. This information has primarily been sourced from CS-VUE, the NZ Transport Agency, the Auckland Motorway Alliance (AMA) and AC.

Table 4 Existing resource consents

Outfall number	Project	Consent Reference	Relevant stormwater management conditions
OF4, OF5	State Highway 1 Albany Bus Station Ramps (2004)	29776	Oteha Valley Road Pond South - Alpurt A1 Pond 30 - 27,590m^2 for 75% TSS removal and 34.5mm detention McClymonts Road Pond South - Alpurt A1 Pond 32 - 11,880m^2 for 75% TSS removal McClymonts Road Pond North South - Alpurt A1 Pond 31 - 10,019m^2 for 75% TSS removal and 34.5mm detention

The existing discharges from the stormwater ponds to AC's stormwater network are covered by AC's existing Network Discharge Consent (NDC - 31819/33076).

2.4.4 Existing Drainage Channels

There are a number of existing engineered, grassed swales throughout the Project area that currently provide informal treatment of stormwater runoff from existing impervious areas of the motorway within the Project area. These drainage channels were not intended or designed to provide treatment of stormwater runoff in accordance with TP10. Particular channels to note are:

- UHH2G – A vegetated channel adjacent to the Greville Road northbound off-ramp. This device provides informal pre-treatment of runoff from the Greville Road northbound off-ramp (refer to Stormwater Layout Plan Drawing 1404 in **Appendix A**), and conveys stormwater to the existing Alpurt Pond 35 located at CH14025; and
- Albany ramps – a series vegetated stormwater channels discharge to the existing Alpurt Ponds located between the Albany on and off ramps (refer to Stormwater Layout Plans Sheet 2 in **Appendix A**). These devices also provide informal pre-treatment of runoff from the existing motorway.

There are also a number of existing artificial watercourses located throughout the Project area that were constructed for conveyance of stormwater runoff between culverts and around infrastructure associated with past projects. Of particular note are the drainage channels within the RWWTP area which are as follows:

- The artificial watercourses located immediately south of Pond 1. These receive flows from the existing 1350mm diameter culvert (CU-EX-13) under SH18 from Caribbean Drive, which services the Unsworth Heights residential catchment (refer to Stormwater Layout Plan Drawing 1408 in **Appendix A**);

- The artificial watercourse that connects the existing 1350 mm diameter culvert (CU-EX-11) under Pond 2 to the existing 1200 mm diameter culvert (CU-EX-10) under SH1 at Chainage 15000 (refer to Stormwater Layout Plan Drawing 1405 in **Appendix A**).

The RWWTP design drawings provided by Watercare indicate that these watercourses were installed as part of the drainage works for Pond 2 in 1971. The watercourses were not shown on the drawings to provide any dedicated stormwater treatment function. The existing watercourses are in good condition with no signs of erosion observed, (refer to site photos provided in **Appendix C2**).

2.4.5 Existing Auckland Council Stormwater Management Devices

There are three existing AC stormwater management devices within the Project area that are affected by works associated with the Project area (as shown in **Figure 6** below):

- Moro Pond (attenuation only) – volume approx. 50m^3;
- ARC Refuse Pond (treatment and attenuation) – water quality volume (WQV) approx. 1,600m^3 and live volume approx. 3,400m^3; and
- Constellation Pond (attenuation only) – volume approx. 19,100m^3.

These existing ponds receive piped stormwater flow from upstream residential and industrial catchments south of SH18 and east of SH1 (outside of the Project area). All three ponds ultimately discharge to the modified watercourse north of Watercare's RWWTP Pond 1 via OF12.

A study was commissioned by AC and undertaken by SKM in 2012 to determine the treatment and detention performance of existing AC ponds in the RWTTP area. **Table 5** summarises the treatment and detention performance of the ARC Refuse Pond, Moro Pond and Constellation Pond, as reported in the above study. Further details on the existing ponds are contained in the SKM report *Stormwater Ponds Upgrade Rosedale Wastewater Treatment Plan Area – Assessment of Improvement in Stormwater Treatment Efficiency* (November, 2012).

Table 5 Existing AC Ponds Treatment and Detention Performance

Pond	Estimated Treatment Efficiency (TSS Removal)	Detention Volume (% of TP10)
ARC Refuse Pond	<10%	71% of required volume
Constellation Pond	<10%	>100% of required volume
Moro Pond	Moro Pond not reported in SKM report	

Further discussion on the performance of the AC ponds and provisions for maintaining their existing capacity in the proposed design is provided in **Sections 2.4.5, 4 and 8.6**.

Figure 6	Existing Auckland Council Stormwater Management Devices

2.5 Watercare's Rosedale Wastewater Treatment Plant

Watercare's RWWTP is located adjacent to SH1 north of Constellation Drive.

There are two constructed ponds that form part of the RWWTP infrastructure. The ponds are located in the upper section of the Oteha Valley catchment (refer **Figure 3**), and have been constructed over natural drainage paths, effectively cutting off the stormwater network upstream of the ponds from the network downstream. In extreme storm events, the ponds form part of the Oteha Valley stormwater network, as described below.

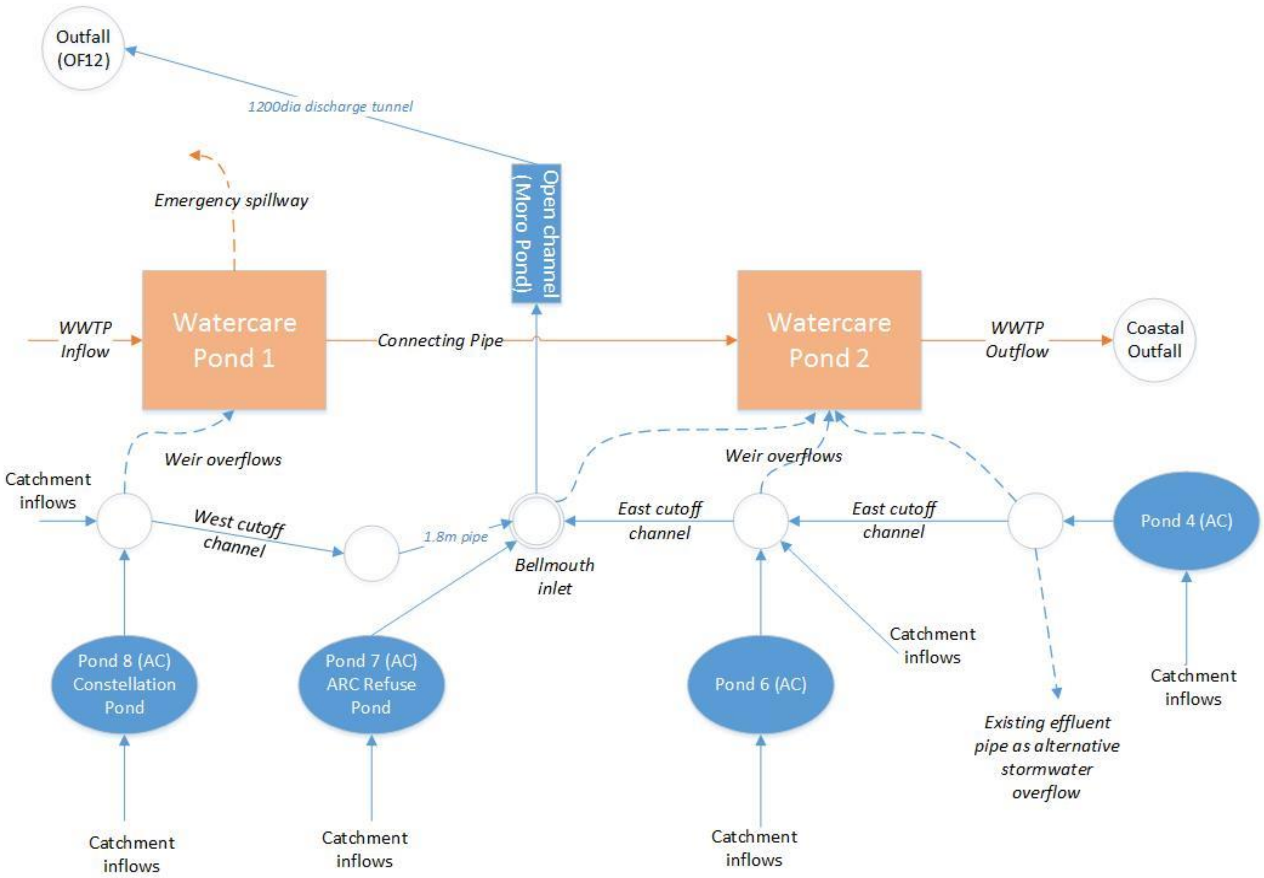
Pond 1 is located to the west of SH1 and receives (partially treated) wastewater inflow from the west. Pond 2 is located to the east of SH1 and discharges treated wastewater by gravity to the coast at the eastern end of Pond 2, via a 3km long tunnel. There is a pond link between the ponds that allows flow between the ponds.

Watercare has confirmed that Pond 1 is required for treatment of wastewater, but Pond 2 is not required for treatment of wastewater. This allows the use of Pond 2 for stormwater management without impacting on the wastewater treatment performance of the plant.

Pond 1 has an emergency spillway located on its northern side, however this spillway is not activated for events up to the 100-year ARI. There are existing artificial (bunded) watercourses that run along the southern side of both ponds, which convey stormwater runoff from upstream catchments (mostly residential and commercial), and discharge the runoff downstream of the ponds. These are referred to as ‘West Cutoff Channel’ and ‘East Cutoff Channel’ in the schematic below. During the 10-year ARI event and greater, stormwater overtops the watercourse bunds at both ponds. Therefore, both ponds also provide a storage function for stormwater runoff from Auckland Council catchments in the extreme storm events.

Figure 7 contains a schematic showing the stormwater systems forming part of, and surrounding, the Watercare ponds.

Figure 7 Watercare RWWTP Stormwater System Schematic



2.6 Existing Flooding and Flood Risk

To understand all historical and current issues associated with flooding or flood risk within the Project area and over the areas surrounding the Project, the following information sources have been reviewed:

- Stormwater modelling reports and models provided by AC (AC, 2013 and NSCC, 2009); and
- Flood maps provided by AC in the stormwater modelling reports (Appendix I in the Oteha Valley Catchment Modelling Report, and Appendix H in the Lucas Creek Catchment Modelling Report).

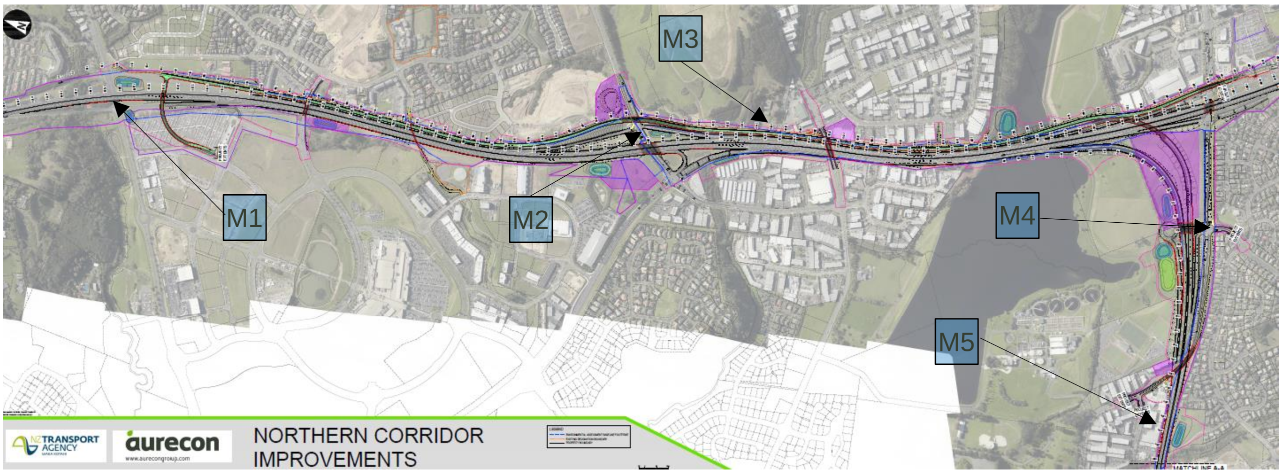
Discussions have also occurred with current network operators AC, AMA, Watercare and Auckland Transport.

The identified motorway flood risk locations are described below and are shown in **Figure 8**:

- M1: SH1 Oteha Valley Road Interchange – Flooding on local road under motorway;
- M2: SH1 Greville Road Interchange – Flooding on local road under motorway;
- M3: SH1 Rosedale Road – Floodplain adjacent to motorway;
- M4: SH18 – Caribbean Drive Intersection; and
- M5: SH18 – Major overland flow path parallel to eastbound carriageway.

The above list only identifies flood risks relating to the motorway and associated local roads, and excludes flood risks for other properties upstream and downstream of the Project.

Figure 8 Location of existing flood issues in relation to the motorway identified from the AC models and discussions with stakeholders



In the Oteha Valley catchment, AC (2013) has identified 39 properties with buildings at risk of floor flooding, and 597 properties within the 100-year ARI floodplain. Within the Lucas Creek catchment, NSCC (2009) identified 4 properties with buildings within the 100-year ARI floodplain (but not at risk of floor flooding), and a further 87 properties within the 100-year ARI floodplain. For further details of which properties have existing flood risks, refer to **Section 5.3.3**.

3 Assessment Methodology

3.1 Overview

This Section provides a description of the methodology used for the assessment of stormwater quality and quantity effects. The assessment methodology also involved extensive consultation with key stakeholders, as described below.

3.2 Stormwater Quantity Management Assessment

3.2.1 Hydrological Parameters

The rainfall data used for the hydrological assessment, including attenuation requirements for runoff from the Project area, has been derived from the 24 hour rainfall depths provided in AC's Technical Publication 108 (TP108).

Climate change adjustments have been applied to rainfall estimates based on the guideline, *Ministry for the Environment – Preparing for Climate Change, A Guide for Local Government in New Zealand* (MfE, July 2008). The mid-range temperature increase has been be used in accordance with AC Stormwater Code of Practice (2015). As the Ministry for the Environment's (MfE) temperature change predictions only extend to 2090, a linear extrapolation from year 1990 has been applied to the MfE mid-range temperature change to predict the increase at the end of the 100-year design life (~2121). Based on this methodology, a temperature increase of 2.7 degrees to year 2121 has been adopted.

All references to rainfall runoff within this document include climate change predictions to year 2121 unless otherwise stated. Climate change adjustments are not required for stormwater treatment, detention and retention rainfalls in accordance with TR2013/035. This approach has been confirmed with AC.

The rainfall data used for stormwater treatment and detention of runoff over the Project has been derived from the 95th and 90th percentile rainfall depths provided in AC TR2013/035 (refer **Figure 13** and **Figure 14** of AC TR2013/035[2]) for Stormwater Management Area controls (SMAF), SMAF1 and SMAF2 areas respectively. The rainfall depth for retention is 5mm for both SMAF1 and SMAF2 areas (refer E10.6.4 of the Auckland Unitary Plan – Operative in Part (AUP)).

The following rainfall depths have been used to calculate catchment stormwater runoff for the Project area. **Appendix E** provides further details of the rainfall depths and intensities used.

Table 6 Project rainfall depths

24-Hour Rainfall Depth (mm)				
TR2013/035 without climate change		TP108 with climate change to 2121		
90th Percentile – WQV and SMAF2 Detention	95th Percentile – SMAF1 Detention	2 year ARI	10 year ARI	100 year ARI
26*	37*	89	169	270

* No climate change adjustments required

[2] AC TR2013/035 available from AC website: http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/planspoliciespublications/technicalpublications/tr2013035aucklandunitaryplanstormwatermanagementprovisionswithappendices.pdf

3.2.2 Stormwater Quantity Management

The criteria for stormwater quantity management for runoff from the Project has been determined taking into account:

- The AUP requirements (as set out in **Section 5.2** below);
- Erosion potential downstream;
- Flooding downstream and upstream of discharge point; and
- Downstream and upstream network capacity.

In sub-catchments where existing ponds provide detention and/or attenuation, existing volumes and outlet information have been determined using survey data and historic project drawings (design drawings and as-built drawings). The existing detention volumes and peak flow rates for the critical storm events (2-year, 10-year and 100-year ARI) have been determined using HEC-HMS v4.0. For catchments with no existing stormwater quantity management devices, the TP108 graphical method has been used to determine existing peak flow rates for critical storm events.

The detention and attenuation volume required have been determined using the TP108 graphical method for the volume difference between the pre- and post-development scenario for the rainfall event required. For detention, these are the 95th and 90th percentile rainfall events for SMAF1 and SMAF2 areas respectively. For attenuation, these are the 10-year ARI or 100-year ARI event, depending on downstream flooding potential. Where multiple wetlands are proposed within a catchment, the required volume is distributed to all wetlands based on the percentage of the total catchment that the wetland is serving. In catchments where existing ponds are removed, the existing detention volume has also been included in the proposed wetlands.

The post-development attenuation peak flows have been determined using HEC-HMS v4.0 and the TP108 graphical method. In catchments where there are multiple wetlands or discharges, or existing ponds, HEC-HMS has been used to calculate the post-development peak flow. This provides a more accurate result as HEC-HMS takes into account difference in peak flow timing and wetland outflows. Wetland outlets have been sized in HEC-HMS to ensure post-development peak flow rates matched pre-development flow rates. For catchments with one single wetland and no existing stormwater quantity management devices, the post-development peak flows have been calculated with orifice and weir formulae, in accordance with TP10. The peak flow attenuation results for each catchment are provided in **Section 5.3**.

The proposed attenuation wetlands and dry ponds have been included in the post-development flood models (refer to **Section 3.2.3**) to determine the wider flooding effects upstream and downstream of the motorway.

3.2.3 Flood Modelling

Flood models for the Lucas Creek catchment and Oteha Valley catchments have been provided by AC[3] and used as the basis for the flood risk assessment and design of the proposed stormwater management devices.

Hydrological and hydraulic modelling for catchments and existing drainage networks that surround and cross the Project has been undertaken to ensure the potential effects associated with flood risk can be appropriately managed. The objective of the flood management solution is to achieve hydraulic neutrality relative to an existing hydrological and hydraulic baseline provided by AC to avoid, remedy or mitigate potential flood effects associated with the Project.

[3] Provided by Auckland Council on 27 April 2016.

3.2.3.1 Oteha Valley Catchment Hydraulic Model

AC has developed a stormwater model for the Oteha Valley catchment (AC, July 2013). The model has been developed using the MIKE FLOOD[4] modelling software which is industry-standard and widely used in New Zealand. The model was developed in accordance with AC's Stormwater Flood Modelling Specifications (AC, 2012) and includes both a hydrological model (based on TP108 rainfall-runoff modelling methods) and a hydraulic model (based on free surface gradually varied unsteady flow equations).

The purpose of the AC model development was to identify habitable floors at risk of flooding and to assess the performance of the existing stormwater drainage network system.

As part of the model development, AC validated the model against measured data at two long-term permanent gauges for three storm events (up to a 10-year ARI event), as well as historical flood incident information. Results found that according to the standard stormwater hydraulic modelling specifications: "in general the model was validated within reasonable agreement with the measured gauge data considering this large catchment with complex stormwater drainage system" (AC, 2013). Validation results of the model are provided in **Appendix E** of the Oteha Valley Catchment Stormwater Modelling - Model Build and System Performance Report (AC, 2013).

Model development also included a sensitivity analysis of the model input parameters on the predicted flows and flood levels. Sensitivity was carried out on the following parameters:

- Model sensitivity to the hydrological rainfall-runoff model was undertaken by varying the pervious area Curve Number (CN) between 61 and 74. Results showed up to a 13% decrease in peak flows and 7% decrease in flood depths.
- Model sensitivity to the Manning's roughness value was also undertaken and found that the roughness adopted for natural stream had a significant effect on the predicted peak flows and flood levels. A 25% increase in channel roughness provided an 8.5% decrease in peak flows and 330mm increase in flood levels. The report notes that this is still within the recommended 500mm freeboard above the predicted 100-year ARI flood level.
- Model sensitivity to rainfall variability over the catchment was undertaken and found to have a significant effect on the predicted peak flows and depths, with up to a 15% peak depth difference compared to measured peak depth.

AC provided models for both the 'Existing Development' (ED) and 'Maximum Probable Development' (MPD) land development scenarios.

Note that the hydraulic model consists of coupled (linked) one-dimensional and two-dimensional components. The two-dimensional component is limited to the Oteha Stream floodplain, and does not cover all the flooding issues which are potentially affected by the Project. Therefore, the one-dimensional model (MIKE URBAN[5]) results are presented for this assessment.

3.2.3.2 Lucas Creek Catchment Hydraulic Model

NSCC developed a stormwater model for the Lucas Creek catchment (NSCC, 2009), using the MOUSE[6] software (DHI, 2005). The model was developed in accordance with NSCC's standard stormwater flood modelling specifications. The model includes both a hydrological model (based on TP108 rainfall-runoff modelling methods) and a hydraulic model (based on 1-dimensional free surface gradually varied unsteady flow equations).

The purpose of the model development was to determine design flows, flood levels and flood extents, identify the level of service of existing infrastructure, identify habitable floor levels at risk of flooding,

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[4] DHI Water & Environment 2011, MIKE FLOOD version 2011, Hørsholm, Denmark.
[5] DHI Water & Environment 2016, MIKE URBAN version 2016, Hørsholm, Denmark.
[6] DHI Water & Environment 2005, MOUSE version 2005, Hørsholm, Denmark. Note that the MOUSE engine has now been incorporated into MIKE URBAN.

and produce flood hazard mapping. We note that this is not a Rapid Flood Hazard Assessment (RFHA) model, which are generally very conservative in terms of peak flood levels as it ignores the piped stormwater network. RFHA models are generally used to develop an understanding of flooding issues and overland flow paths prior to development of more accurate models.

Model validation was undertaken by NSCC as part of the model development process against both gauged flow and stage (water depth) for two storm events at two gauging stations. Results found that the validation model was reasonable in regards to peak flow and timing, however the model may be slightly under predicting peaks at one gauge location and over predicting volume at another gauge location (NSCC, 2009).

Model development included a sensitivity analysis of the catchment lag parameter used in the TP108 methodology. Results found a minimal difference to peak timing.

Note that the Lucas Creek model has no two-dimensional hydraulic component, and therefore only one-dimensional results are presented for this assessment.

3.2.3.3 Stormwater Models 'Pre-Development' Scenario

The AC Oteha Valley stormwater model and the NSCC Lucas Creek stormwater model have been adopted for the purposes of this environmental assessment, and the following changes made to the models' base scenarios (the 'pre-development' scenario):

- In accordance with the NZ Transport Agency requirements for a 100-year design life, the design rainfall depths have been adjusted for climate change to year 2121 as described in Section 3.2.3.5;
- The rainfall intensity and temporal pattern have been updated in accordance with the latest AC Code of Practice for Land Development and Subdivision; Chapter 4 - Stormwater (AC, November 2015);
- The model has been updated to Version 2016 of the MIKE FLOOD software; and
- The Lucas Creek model has been updated to reflect the catchment land use in the latest digital impervious surfaces layer provided by AC ('Impervious Surfaces 2008'), consistent with the Oteha Valley stormwater model.

The pre-development stormwater models have been used for the following purposes:

- Determining and comparing pre and post-development effects in the wider catchment; and
- Options assessment for the existing AC pond relocation adjacent to the RWWTP.

Refer to the AC model development reports (AC, 2013 and NSCC, 2009) for further details on the flood model setup, assumptions and limitations.

3.2.3.4 Stormwater Models 'Post-Development' Scenario

The flood effects of the Project have been assessed using the Oteha Valley and Lucas Creek stormwater models, developed by AC (2013) and NSCC (2009), respectively.

The post-development models are based on the pre-development models, which have been updated to reflect the changes associated with the Project works, including:

- Changes to the hydrological model:
  - Revised catchment delineation to reflect proposed Project drainage; and
  - Revised impervious areas and runoff parameters associated with the new pavement of the Project works.
- Changes to the hydraulic model:

- Proposed stormwater management wetlands and ponds added to the model (refer **Section 3.2.2** for sizing methodology), including revised inflow source locations (catchment connections) for the proposed wetland catchments;
- The change to the overland flow path drainage at the north of UHH near the Unsworth Drive intersection;
- The change to the storage volume at the flood prone area at 117 and 121 Rosedale Road (CH14350);
- Changes associated with the preferred AC Pond option (refer to **Section 8.6.4**); and
- New cross culverts and upgrades to existing cross culverts (culvert extensions, etc.).

3.2.3.5 Land Development Scenario for Flood Modelling

The ED scenario including climate change has been used for the assessment of the post-development flooding effects (rather than the MPD scenario), so that the increase in impervious area due to the Project is accounted for (note that in the MPD scenario, the motorway widening lies completely within the transport corridor zone which has a maximum imperviousness of 100%. This means that under the MPD scenario, the increase in impervious area due to the motorway widening would not show an increase in runoff). The ED scenario uses the latest impervious footprint as assessed by AC in 2008 (AC, "Impervious Surfaces 2008").

The existing culvert capacity assessment and sizing of new culverts has been undertaken using the MPD scenario. This approach allows the culverts to be sized to accommodate future development in the catchment. The MPD scenarios in the models provided by AC were out of date and so were updated to the AUP zoning maps and maximum impervious area thresholds.

A comparison of the ED and MPD scenario (both including climate change) in the Oteha Valley catchment shows that the peak discharges for the ED scenario are generally only approximately 5% less than those of the MPD scenario. This reinforces that the existing catchment is already highly developed, particularly in the upstream portion of the catchment.

3.2.3.6 Flood Modelling Collaboration with Auckland Council

As noted above, the flood models received from AC have been assessed and used as the basis for the flood risk assessment undertaken for the Project. To confirm conformance with the AC standard stormwater hydraulic modelling specifications, preliminary versions of the model (i.e. options assessment) were sent to AC for review and comment.

In addition, a number of meetings were held with AC to confirm the assessment methodology applied was fit for the purpose of assessing the impact of the Project on the upstream and downstream receiving environments. This collaboration has been used to inform the final model developed and used for the assessment for the Project. Full details of the correspondence with AC on the modelling assessments undertaken (including the feedback received from AC during their review of the models) is included in **Appendix F**.

3.2.3.7 Flood Model Summary

In summary, the Oteha Valley and Lucas Creek stormwater models provided by AC have been reviewed to a level of detail considered sufficient for the purposes of this impact assessment. However, due to the size of the stormwater models this review has not included an assessment of every component of the model, and the use of the models relies on the accuracy of the model-build. Notwithstanding, the models are considered to be fit-for-purpose for the assessment of Project impacts on flooding in the catchments, and are particularly suited for assessing cumulative impacts of multiple discharges in the wider catchment. The reasons for the confidence in the models are as follows:

- The models have been developed by AC and are consistent with AC's Stormwater Flood Modelling Specifications (AC, 2012);
- The hydrological (rainfall-runoff) model component uses the TP108 methodology, which was developed on behalf of Auckland Regional Council (ARC) (now AC) based on gauged catchments within the Auckland region, and is a standard tool for hydrological modelling in Auckland;
- The models have undergone validation and sensitivity analysis testing;
- The model components are based on best available data such as AC GIS asset information, surveyed information, as-built plans, LiDAR, and site visits;
- The models extend sufficiently upstream and downstream of the Project designation so as to be able to assess cumulative impacts of multiple discharges in the wider catchment; and
- The purpose of the model development by AC is consistent with the use of the model for the impact assessment, namely to determine design flows, flood levels and flood extents, identify the level of service of existing infrastructure, identify habitable floor levels at risk of flooding, and produce flood hazard mapping. This is in contrast with RFHA models which are usually developed for identifying flooding issues and overland flow paths prior to development of more accurate models.

For these reasons, the stormwater models provided by AC are considered the best available tool for assessing flooding impacts in the Oteha Valley and Lucas Creek catchment and have been adopted for this assessment.

3.2.4 Cross Drainage Structures

Existing cross drainage structures which are potentially impacted by the Project are identified in **Appendix G**. Estimation of the peak discharges for each culvert has been undertaken in two ways:

- TP108 methodology (ARC, 1999); and
- Overall catchment stormwater models (AC, 2013 and NSCC, 2009).

Both methods assume the MPD land development scenario and incorporate climate change to 2121. The TP108 methodology is expected to be more conservative as it is a lumped catchment method and does not take into account storage (ponds) within the catchment, or hydrograph timing effects of sub-catchments.

An assessment of proposed culvert extensions and upgrades on peak discharges and peak flood levels has been undertaken as part of the overall catchment flood modelling (refer to **Section 3.2.3.4**). New culverts have been sized with using TP108 methodology and hydraulic analysis using the HY-8 software, and were incorporated into the post-development stormwater flood model.

Culvert assessment has been undertaken in accordance with AC Stormwater Code of Practice (2015), and blockage has been assessed on a case-by-case basis considering the catchment characteristics at each culvert location. A risk-based assessment of potential culvert blockage as described in ARR (2016) has been undertaken accounting for the following factors known to influence blockage:

- Debris type and dimensions;
- Debris availability;
- Debris mobility;
- Debris transportability; and
- Structure interaction (mechanism of blockage).

The assessment of blockage was preliminary and will be refined during detailed design.

3.3 Stormwater Quality Management Assessment

The assessment of the existing treatment performance of the motorway was carried out using historic design information (drawings and reports), hydrological information provided by AC, consent documentation, a physical survey of existing assets and discussions with the relevant network operators.

The assessment also involved calculating the impervious areas over the existing motorway using LiDAR survey and aerial photography flown in June 2016. The existing stormwater ponds affected by the works (proposed to be removed) were surveyed to confirm their size and capacity.

The assessment of existing catchment information has been used to develop the proposed design for the Project as discussed further in **Section 5.4** below.

3.4 Stakeholder Consultation

As part of the design process, extensive consultation has occurred with key stakeholders comprising AC, AMA, Watercare, Iwi and AC Parks and their feedback has been considered. A summary of the consultation undertaken and the design changes made in response to that feedback is set out in **Appendix F**.

4 Project Design

4.1 Overview

Due to the physical constraints within a confined road corridor in a highly urbanised environment, stormwater treatment and attenuation is proposed to be provided by a combination of wetlands, dry and wet ponds, swales, and proprietary devices.

The following design principles have been adopted:

- Incorporation of a total stormwater management system (TSMS) that mimics the existing hydrologic regime and setting – this includes collection and conveyance network, treatment devices, stormwater cross drainage, culverts and diversions, and outfalls including erosion protection;
- Adoption of the BPO to avoid, remedy or mitigate adverse environmental effects that are a result of the Project works, determined through a robust evaluation of options and alternatives;
- Improvement of the discharge quality from impervious surfaces within the existing designation which is currently discharged untreated;
- Consideration of stormwater operational implications throughout the design life, including suitable access for maintenance;
- Consideration of the potential effects of increased flows from increased impervious areas on upstream and downstream networks and receiving environments;
- Consideration of the preferences of the AMA and Safety in Design considerations with respect to construction, operation, maintenance and general access for stormwater management devices have been taken into account (refer to **Appendix H**); and
- Provision of stormwater management devices that comply with stormwater quality and quantity requirements (treatment, detention, retention and attenuation) set by AC, including the AUP provisions, and the NZ Transport Agency.

Existing stormwater reticulation and stormwater management assets (including swales, ponds, wetlands and proprietary devices) are proposed to be retained where possible. The criteria for retaining existing assets include that the:

- Location of the existing asset is not affected by the proposed works;
- Condition of existing asset is acceptable (i.e. no major structural defects and acceptable design life retained); and
- Hydraulic capacity of existing asset is acceptable.

Where any of the above criteria cannot be met, the existing asset is proposed to be abandoned and/or replaced.

Figure 9 shows an overall layout of the stormwater design proposal. For details of the stormwater layout, refer to the Stormwater Layout Plans in **Appendix A**.

New Wetlands

In summary, the following new wetlands are proposed:

- Oteha Valley East and West Wetlands will discharge to Lucas Creek;
- McClymonts Wetland will discharge to an ephemeral channel upstream of the Albany Lakes Reserve;
- Greville Wetland will discharge to Oteha Stream;

- Caribbean Wetland will discharge to the artificial watercourse south of Watercare Pond 1; and
- Rook Wetland will discharge to Alexandra Stream.

Existing ponds to be retained and modified

Three existing stormwater ponds are to be retained but their catchments will be modified as follows:

- Alpurt A1 Pond 30 (existing catchment proposed to be decreased);
- Alpurt A1 Pond 34 (outlet proposed to be modified to increase storage volume); and
- Alpurt Pond 35 (outlet proposed to be modified to increase storage volume).

New Dry Ponds

Two dry ponds are proposed which provide an attenuation function. These ponds do not provide treatment function. These ponds are outlined in **Table 7** below.

Table 7 Proposed Attenuation Dry Ponds Summary

Dry Pond	Location	Sub-catchment	Impervious Catchment Area (ha)	Pervious Catchment Area (ha)	Live volume (m^3)
Greville SB On-Ramp Dry Pond	State Highway 1-CH13900-SB	S2R	0.25	0.07	320
Greville NB Off-Ramp Dry Pond	State Highway 1-CH14110-NB	S2R	2.07	0.02	420

New Treatment Swales

In two sub-catchments, swales are proposed as treatment devices and have been designed in accordance with TR2013/035. The locations of the swales are shown in **Figure 9**.

New Proprietary devices

Stormwater treatment within the Spencer to Rosedale (S2R) catchment is provided by a stormwater proprietary device (StormFilter or similar). The proposed proprietary device has been designed to provide treatment to meet 75% TSS removal for all existing and new HUR pavement areas discharging to the existing Alpurt A1 Pond 35. This pond is currently undersized and provides sub-standard treatment (approx. 55% TSS removal), but will be retained for stormwater quantity management for the Project.

A proprietary device is also proposed for treatment of the PM2AH catchment. This device will ensure 75% TSS removal for all existing and new HUR pavement within this catchment.

Constellation Bus Station

The Constellation Bus Station stormwater reticulation system is proposed to be modified to discharge stormwater runoff from the new impervious surfaces resulting from the bus station alterations. This modification allows new impervious areas from the bus station to be treated and managed by the proposed Moro Wetland. The existing stormwater management devices within the Bus Station will be retained to manage stormwater runoff from the parts of the station that do not form part of the Project.

Auckland Council Stormwater Ponds

There are three existing AC stormwater ponds within the Project area that will be removed due to the earthworks proposed as part of the motorway widening. The existing ponds affected are the Moro

Pond, ARC Refuse Pond and Constellation Pond. The equivalent performance (quantity and quality control) of these three ponds is provided for in the proposed design.

The existing ponds have been surveyed to determine the existing WQV, detention and attenuation volume provided in these devices, to ensure the proposed design is able to replicate the performance of the existing system. The existing stormwater ponds discharge to AC's stormwater network and the replacement ponds will also discharge to AC's network.

Outfalls

There are a number of existing outfalls within the Project area. No changes to existing outfalls are proposed where the peak discharges are unchanged. The exception is OF12, where peak discharges are increased. The outfall has been assessed and downstream stream protection works are proposed (refer to **Section 7.2**).

Existing outfalls that are to be retained and will remain unmodified are as follows (refer to **Figure 9** for locations of outfalls):

- Lucas Creek: OF1, OF2 and OF4;
- Ephemeral channel at McClymonts Road: OF6;
- Oteha Stream: OF9 and OF11;
- Modified watercourse north of Watercare Pond 1: OF12 (works proposed downstream of outfall to mitigate increased erosion potential); and
- Alexandra Stream: OF17

New and modified outfalls to the following streams and watercourses are proposed:

- Lucas Creek: OF3;
- Ephemeral channel at McClymonts Road: OF5;
- Artificial watercourse at Rathmullen Place: OF7;
- Oteha Stream: OF8 and OF10;
- Artificial watercourses south of Watercare Ponds: OF13, OF14 and OF 15; and
- Alexandra Stream: OF16 and OF18

The above outfalls do not include discharges to AC's pipe network. Discharges to AC's pipe network will be applied for under AC's Engineering Approval Process.

Stormwater Reticulation

Stormwater reticulation has been developed to a conceptual level. During detailed design, the reticulation system will be designed for the 10 year ARI rainfall event with secondary or overflow systems designed for the 100 year ARI rainfall event. In the locations where there is no secondary overland flow path the pipe system will be designed to convey the 100-year ARI peak flow.

Culverts

A number of existing culverts cross the Project. These pipes convey cross catchment flow from one side of the motorway to the other and typically connect existing AC piped catchments/networks. The existing and proposed culverts are shown on the Stormwater Layout Plans in **Appendix A**.

Unless otherwise approved by AC and the NZ Transport Agency, all culverts and pipes (existing and new) that cross the State highway will:

- Convey the 10 year ARI storm event flow without surcharge of the pipe for the MPD scenario; and

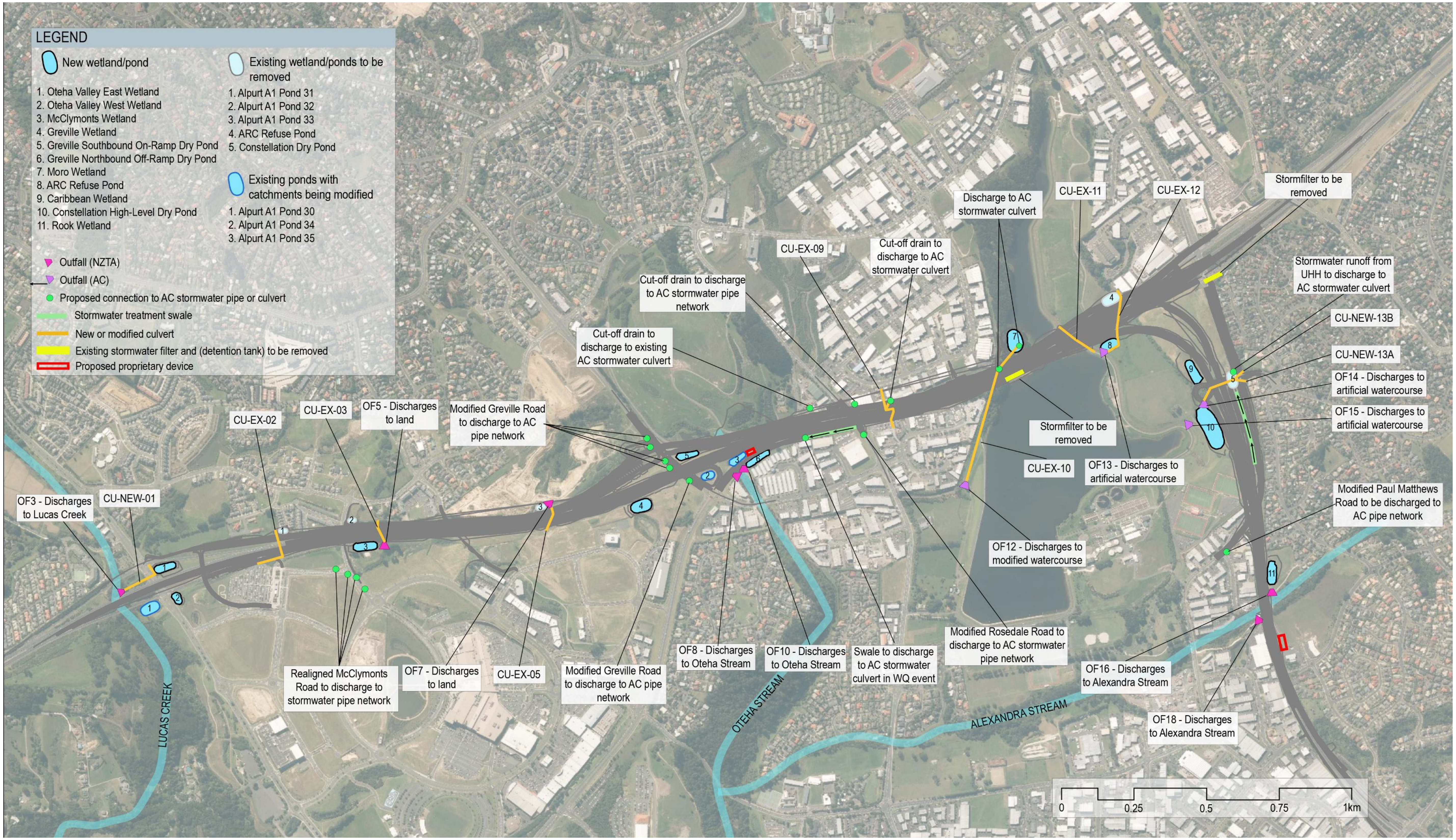
- Convey the 100 year ARI storm event flow without surcharge of the pipe more than 2m above the pipe soffit (at headwall inlets only), whilst ensuring a minimum 500mm freeboard is provided from the peak water level to the outer edge line level for the MPD scenario.

At this stage of the Project, no condition assessment of the culverts has been carried out however where existing culverts proposed to be retained are found to be defective or in poor condition during the detailed design phases, they will be replaced with the same size culvert to minimise impacts on the upstream and downstream environment.

Cut-off drains

Cut-off drains for the Project have been preliminarily sized to capture and convey the 100-year ARI event in the MPD scenario without overtopping.

Figure 9 Proposed Stormwater Devices and Outfall Locations



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4.2 Design Standards

The design and evaluation of the stormwater drainage and treatment for the Project has taken into account the key design standards and guidance documents listed in **Appendix J**.

There is a suite of proposed AC stormwater standards that are currently in draft (e.g. draft GD01 that will replace TP10) and are not currently publicly available. These documents have not been used in the development of the proposed stormwater management design.

MfE has also recently published *Climate Change Projections for New Zealand* (MFE 1247, June 2016), that supersedes *Climate change effects and impacts assessment: A guidance manual for local government in New Zealand* (ME 870, May 2008). The 2008 document has been adopted for the proposed design, in accordance with the Auckland Council *Code of Practice for Land Development and Subdivision Chapter 4 – Stormwater* (Version 2.0, November 2015). This approach has been agreed with AC.

4.3 Potential Impacts

This section describes the potential (unmitigated) surface water impacts that may result from the Project on the receiving environment. **Table 8** provides a summary of the potential surface water impacts of the Project, and a reference to the section of this report in which the impact is assessed.

Table 8 Potential Surface Water Impacts of the Project

Category	Description	Report Sections for Further Details
Water Quality	Adverse impacts on receiving water quality due to discharges of motorway runoff	Section 6, the Assessment of Surface Water Quality Effects and Assessment of Freshwater Ecological Effects
Flooding	Increased peak flood levels downstream of motorway runoff discharge locations	Section 5.3.3.1
Flooding	Increased peak flood levels upstream of motorway associated with changes to cross drainage infrastructure (culverts) and reduction of storage at ponded locations	Section 5.5
Flooding	Increased flooding impacts associated with changes to overland flow paths adjacent to the motorway	Section 5.6
Hydrologic regime	Cumulative impacts on the hydrologic regime (downstream flow) in receiving environments (in particular the hydrograph recession curve) associated with the proposed detention and attenuation of treated water, and the diversion of flows between sub-catchments	Section 5.3.3.2
Erosion	Increased erosion and changes to stream geomorphology in receiving environments associated with motorway discharges	Section 3.2.2, 5.2
Ecology	Restriction of the passage of aquatic species associated with changes to cross drainage infrastructure (culverts)	Section 8.4 and Assessment of Freshwater Ecological Effects
Ecology	Increased water temperature downstream of motorway discharges associated with additional impervious areas and detention of water in proposed wetlands and ponds	Assessment of Freshwater Ecological Effects

Category	Description	Report Sections for Further Details
Construction water management	Water quality, hydrology, flooding, erosion and ecology impacts during the construction phase of the Project	Assessment of Construction Water Management, Assessment of Surface Water Quality Effects and Assessment of Freshwater Ecological Effects

5 Proposed Stormwater Quantity Management

5.1 Overview

This section provides a description of the proposed stormwater quantity management measures, and a summary of the effects of the Project on the wider catchment.

5.2 AUP Requirements

The purpose of providing flow management is to manage potential increases to stream erosion and downstream flooding as a result of additional runoff from new impervious areas associated with the Project.

Table E10.4.1 (A7) of the AUP provides for development of new impervious areas greater than 5,000m^2 for road, motorway or State Highway within the SMAF 1 and SMAF 2 areas as a restricted discretionary activity subject to compliance with Standards E10.6.1 and E10.6.4.2. The majority of the Project area falls within a SMAF 2 area under the AUP, with only the section of the Project north of Spencer Road falling within a SMAF 1 area.

Standard E10.6.1 requires discharges not to a stream or discharged below RL2m to meet the following standards:

- Hydrological mitigation must be provided on the same site (i.e. within the road reserve or land under the control of the road control authority) as the new or redeveloped impervious area;
- Any stormwater management device or system must be built in accordance with design specifications by a suitably qualified service provider and must be fully operational prior to use of the impervious area;
- 'As built' plans for any stormwater management device or system must be provided to Council within three months of practical completion of the works; and
- Any stormwater management device or system must be operated and maintained in accordance with best practice for the device or system.

Standard E10.6.4.2 requires that stormwater runoff from new impervious areas and any existing impervious areas discharging to the same drainage network point must be managed to achieve the hydrology mitigation requirements specified in Table E10.6.3.1.1. There is an exemption from these requirements where a suitably qualified person has confirmed that soil infiltration rates are less than 2mm/hr or there is no area on the site of sufficient size to accommodate all required infiltration that is free of geotechnical limitations (including slope, setback from infrastructure, building structures or boundaries and water table depth) and rainwater reuse is not available.

The maximum soil infiltration rate expected to be encountered within the Project area is approximately 0.004mm/hr (refer to the technical memo in **Appendix I**). This is significantly less than the 2mm/hr required for retention. Unlike residential and commercial developments, the motorway environment does not provide practical nor safe opportunities for the capture and re-use of the retention volume on-site. As such, no retention is proposed for the Project. In accordance with the AUP, full detention of the 95th and 90th percentile rainfall events is provided using wetlands and/or dry ponds for the SMAF 1 and SMAF 2 areas respectively, without any reduction allowance for retention. This is achieved using controlled outlets in the wetlands and dry ponds.

In considering applications under these rules, a number of policies are relevant.[7] In particular, the water quantity policies require the management of stormwater runoff within SMAF 1 and 2 areas to minimise the effects of stormwater runoff to retain and where possible enhance stream naturalness, biodiversity, bank stability and other values.

Policy E10.3.2 requires hydrological mitigation in SMAF 1 and 2 areas where there are new impervious areas. Policy E10.3.3 recognises that there are limits to the hydrological mitigation that can practicably be achieved, particularly where there are space limitations.

Similarly, Policy E10.3.3 recognises that there may be limitations to where hydrology mitigation can practicably be achieved in some circumstances, particularly in association with redevelopment, including:

(a) Space limitations;

(b) Requirements to provide for other utility services; and

(c) The function of roads as overland flow paths conveying stormwater runoff from surrounding land uses which the road controlling authority has limited ability to control.

Increased flooding on properties outside of the Project area is controlled by Chapter E8 of the AUP. Standard E8.6.1(3) requires that the diversion and discharge must not result in or increase the flooding of other properties in rainfall events up to the 10 per cent annual exceedance probability (AEP) or inundation of buildings on other properties in events up to 1 per cent AEP. Flooding is likely to be increased at several properties downstream of the outfall points within the Lucas Creek and Oteha Valley catchments. As such, Activity Table E8.4.1 Rule A10 applies, and the discharge of stormwater from the Project will be require a discretionary consent.

5.3 Stormwater Quantity Management

5.3.1 Overview

The objective of the Project's flood management controls is to achieve hydraulic neutrality within the catchment. Where this has not been possible (due to physical constraints of not having space available for attenuation areas and the quantum of catchment flow from the additional impervious areas over the Project area), flood levels have been assessed and peak flow attenuation mitigation measures implemented where possible.

5.3.2 Peak Flow Attenuation

A potential impact of increasing the impervious area within a catchment is an increase in the runoff volume and peak flow rate during storm events. Assessment of the unmitigated Project impacts show:

- Increased volume of overflows into the Watercare ponds;
- Peak flood level increases in Alexandra Stream of up to 90mm (extending from the UHH crossing to the confluence with Oteha Stream);
- Peak flood level increases in Oteha Stream of up to 70mm;
- Peak flood level increases in the modified channel downstream of OF12 of up to 110mm;
- Peak flood level increases at buildings flooded in the 100 year ARI MPD event of up to 60mm;
- Peak flood level increases up to 300mm upstream of Albany Lakes Reserve; and
- Peak flood level increases between 30mm to 100mm in Lucas Creek extending to the catchment outlet.

[7] Policy E10.3.1, E10.3.2, E10.3.3, E1.3.1 to E.1.3.5, E1.3.8 and E1.3.9.

One method of compensating for the increase in peak flow rate is to provide attenuation of the runoff through the use of ponds, which extends the duration of the discharge. The proposed level of attenuation has been informed by the AC stormwater models and reports (refer to **Section 3.2.1**).

The level of peak flow attenuation provided at each stormwater discharge location has been determined based on the following:

- Existing property and building flooding issues downstream of discharge locations;
- Location of discharge points within the overall catchment (in regard to timing of flood peaks);
- Receiving flow and channel characteristics downstream of discharge locations; and
- Sensitivity of increased flows and levels as a result of increased impervious area runoff.

Table 9 summarises the flow management proposed for the sub-catchments in the Project area (refer to the Stormwater Catchment Plans in **Appendix B** for the extent of each sub-catchment).

A reduction in peak flows has been achieved with the use of wetlands and dry ponds (refer to **Appendix K** for further information on the wetland and catchment calculations). The AC flood model has been used to determine downstream effects for both the pre- and post-development Project scenarios.

Table 9 Stormwater Flow Management by Sub-catchment

Motorway Sub-catchment	Existing Area (ha)		Proposed Area (ha)		Stormwater Management proposed	Total Pre-Development Peak Flow (m^3/s)	Total Post-Development Peak Flow (m^3/s)	Comment
	Imp	Per	Imp	Per				
Oteha Valley to McClymonts (OV2M)	3.32	2.33	4.44	1.21	WQ, SMAF1 Detention, PFA_{2yr} PFA_{10yr}	$Q_2 = 0.57$ $Q_{10} = 2.13$	$Q_2 = 0.57$ $Q_{10} = 1.93$	Peak flow reduced for Q_2 and Q_{10}. Attenuation of Q_{100} not required.
McClymonts to Spencer (M2S)	1.60	0.88	2.21	0.27	WQ, SMAF1 Detention, PFA_{2yr} PFA_{10yr} PFA_{100yr}	$Q_2 = 0.21$ $Q_{10} = 0.58$ $Q_{100} = 0.98$	$Q_2 = 0.15$ $Q_{10} = 0.54$ $Q_{100} = 0.96$	Peak flow reduced for Q_2, Q_{10} and Q_{100}.
Spencer to Rosedale (S2R)	7.69	9.10	12.13	4.65	WQ, SMAF2 Detention, PFA_{2yr} PFA_{10yr} PFA_{100yr}	$Q_2 = 1.11$ $Q_{10} = 3.38$ $Q_{100} = 6.01$	$Q_2 = 0.71$ $Q_{10} = 1.80$ $Q_{100} = 3.70$	Peak flow reduced for Q_2, Q_{10} and Q_{100}.
Rosedale to Constellation (R2C)	3.70	9.35	8.43	4.62	WQ, SMAF2 Detention, PFA_{2yr} PFA_{10yr} PFA_{100yr}	$Q_2 = 1.26$ $Q_{10} = 3.00$ $Q_{100} = 5.33$	$Q_2 = 1.24$ $Q_{10} = 2.99$ $Q_{100} = 5.33$	Peak flow reduced for Q_2, Q_{10} and Q_{100}.
Constellation to Paul Matthews (C2PM)	2.40	3.97	3.79	2.59	WQ, SMAF2 Detention, PFA_{2yr} PFA_{10yr} PFA_{100yr}	$Q_2 = 0.58$ $Q_{10} = 1.35$ $Q_{100} = 2.39$	$Q_2 = 0.58$ $Q_{10} = 1.33$ $Q_{100} = 2.38$	Peak flow reduced for Q_2, Q_{10} and Q_{100}.
Paul Matthews to Albany Highway (PM2AH)	2.36	4.26	4.89	1.73	WQ, SMAF2, PFA_{2yr} PFA_{10yr}	$Q_2 = 0.55$ $Q_{10} = 1.24$	$Q_2 = 0.39$ $Q_{10} = 0.93$	Peak flow reduced for Q_2 and Q_{10}. Attenuation of Q_{100} not required.

Note: WQ = Water Quality, SMAF = Stormwater Management Area Flow, PFA = Peak Flow Attenuation for the specified ARI flood event.

Discharge locations – Oteha Valley Catchment

The proposed discharge locations in the context of the Oteha Valley catchment are shown in **Figure 10**. In the Oteha Valley catchment, AC's flood assessment (AC, 2013) identifies existing building floor flood risks downstream of the Project in the 100-year ARI event, specifically along the Oteha Stream itself.

Consequently, peak flow attenuation of the 2-year, 10-year and 100-year ARI storm is proposed for discharges within this sub-catchment as part of the Project design. The only exception is discharge to Alexandra Stream, where peak flow attenuation for up to the 10-year ARI storm is proposed, as assessment of the AC flood model shows downstream properties being flooded in the 10-year ARI storm but no building floor flood risks in the 100-year ARI event. The discharge location is approximately 2km upstream of the Alexandra Stream and Oteha Stream confluence (where the flooding risks are identified).

Discharge locations – Lucas Creek Catchment

The proposed discharge locations in the context of the overall Lucas Creek catchment are shown in **Figure 11**. With regard to attenuation in the Lucas Creek catchment:

- The discharge location is directly into Lucas Creek, in the lower half of the catchment;
- The Lucas Creek channel is well-confined downstream of the discharge location; and
- As identified from the Lucas Creek Catchment Stormwater Modelling report (NSCC, 2009), there are no buildings identified as being at risk of flooding in the 100-year ARI storm downstream of the discharge location (on Lucas Creek itself). There are properties within the 10-year ARI floodplain, but the buildings on the properties are not within the floodplain nor within 500mm of the predicted 100-year ARI peak flood levels).

As such, peak flow attenuation for up to the 10-year ARI storm is proposed for discharges to the Lucas Creek Catchment.

Figure 10 Oteha Valley Catchment – Proposed Wetland Discharge Locations

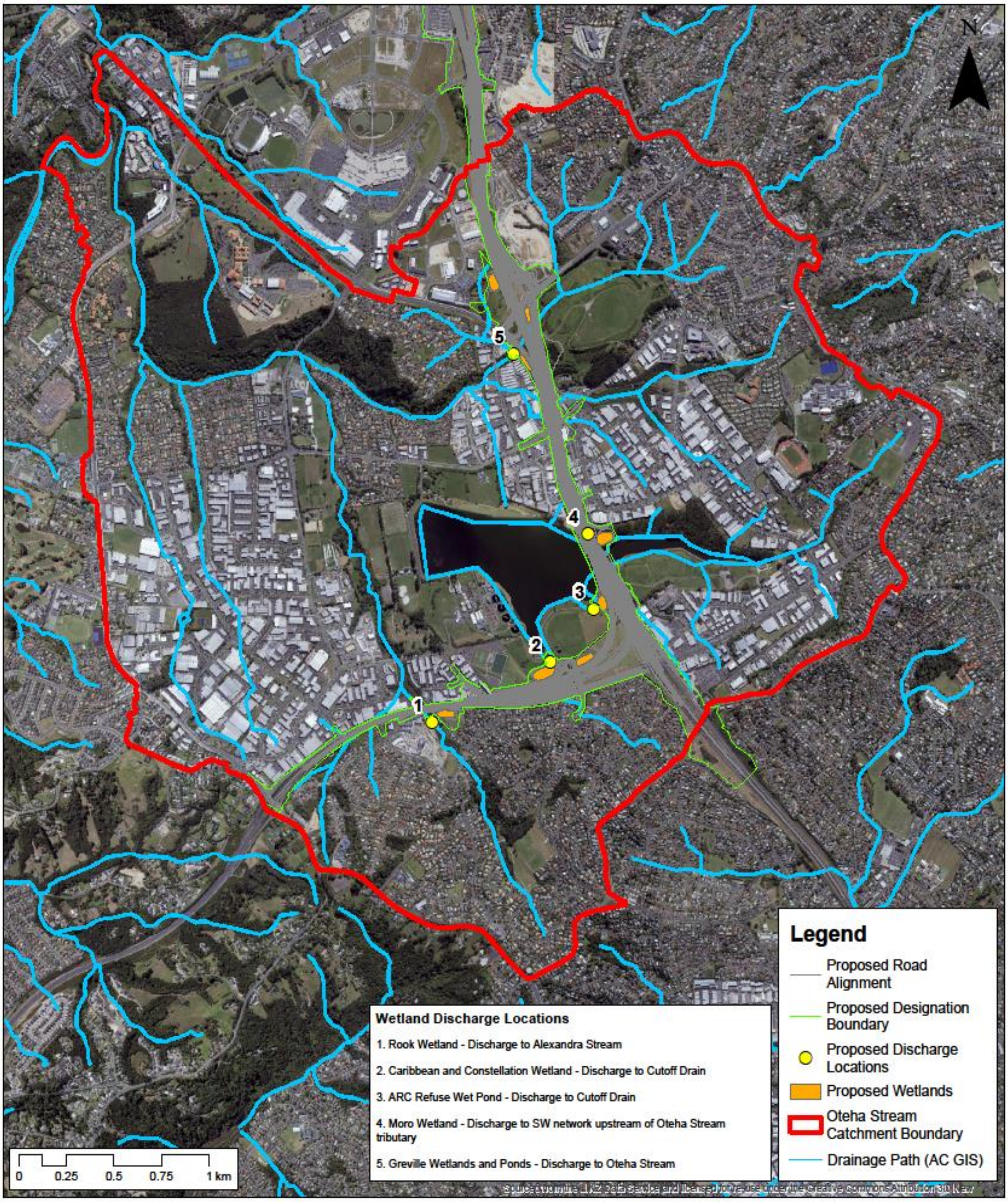

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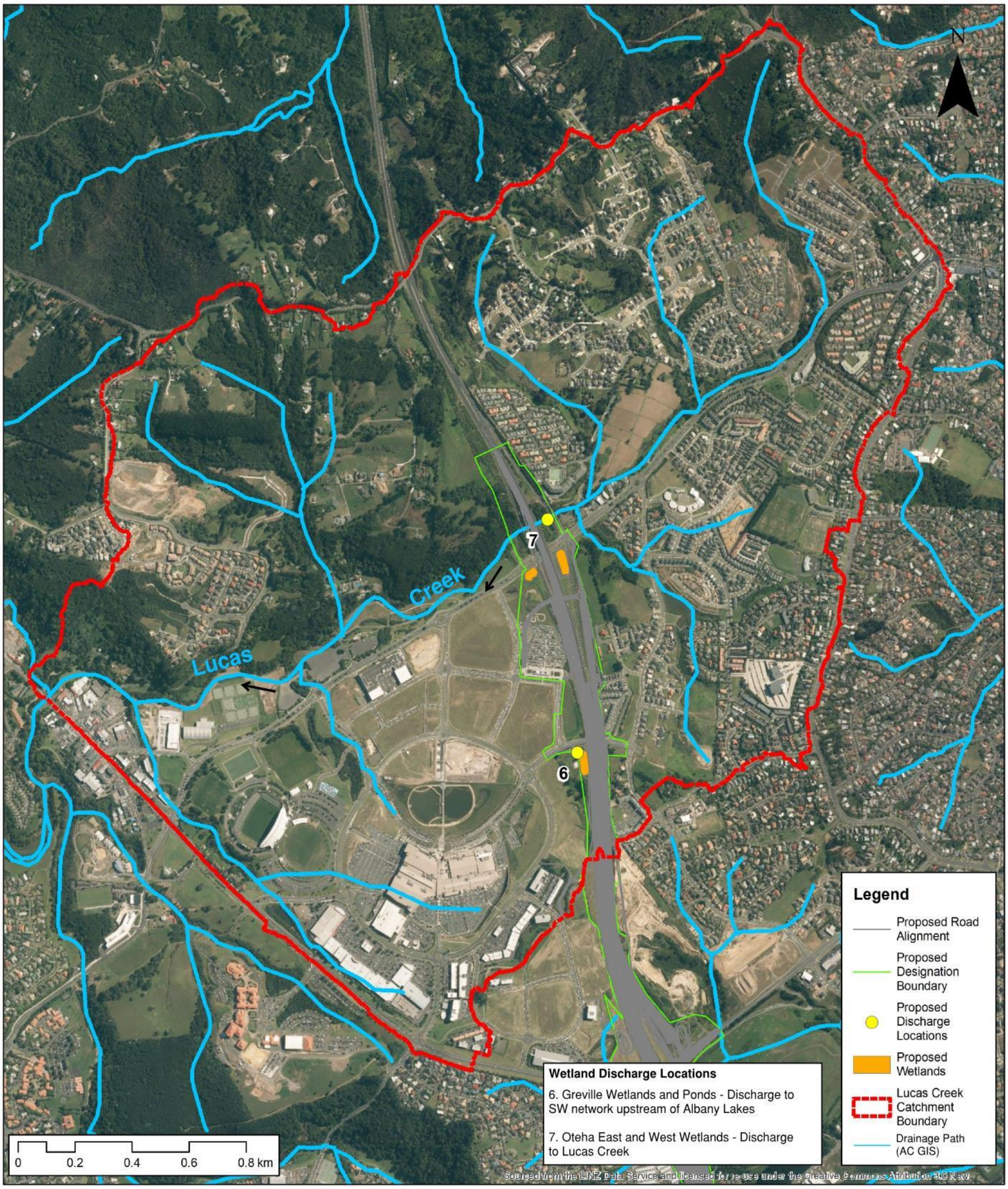
Figure 11 Lucas Creek Catchment – Proposed Wetland Discharge Locations



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5.3.3 Flood Modelling Results

5.3.3.1 Peak Flood Levels and Peak Discharges

The peak flow rates and flood levels for the pre-development and post-development ED scenario (as described in **Section 3.2.3**) have been compared at key reporting locations in the Oteha Valley and Lucas Creek catchments as follows:

- Locations with current risk of flooding potentially affected by the Project, identified from the AC flood maps (AC, 2013); and
- Streams and channels directly downstream and upstream of discharge points.

The stormwater impact assessment for each of the Oteha Valley and Lucas Creek catchments is set out in the following sections.

5.3.3.1.1 Oteha Valley Catchment

The wetland discharge locations in the context of the overall catchment and key reporting locations for pre- and post-development peak flows and water levels are identified in **Figure 12**.

Table 10 summarises the predicted peak water level differences at the key reporting locations in **Figure 12** for the Oteha Valley catchment. **Table A4** in **Appendix L** further details the peak flow rates and levels at the key locations for the Oteha Valley catchment.

A visual representation of the peak water level differences for the 2, 10 and 100 year ARI events at the model node locations (MIKE URBAN component only) is contained in **Appendix L**.

Table 10 **Flood Modelling Results Summary – Predicted Peak Water Level Differences at Key Reporting Locations in the Oteha Valley Catchment (m)**

Location (refer Figure 12)		Predicted Peak Water Level Difference (m)		
		2-year ARI	10-year ARI	100-year ARI
A	Catchment outlet to Lucas Creek (upstream of model boundary)	-0.01	0.00	0.00
B	Downstream of confluence of Alexandra Stream and Oteha Stream	-0.02	-0.01	-0.01
C	Downstream of confluence of Oteha Stream and tributary at Tawa Drive	-0.03	0.00	-0.01
D	Outlet of 1200mm diameter pipe into modified watercourse (OF12)	+0.01	+0.04	+0.04
E	Meadowood Reserve - Caribbean Road/UHH intersection (flood prone location identified by AC with flooding impacting on nearby kindergarten)	-0.30	-0.42	-0.46
F	Upstream of ARC Refuse Pond	-0.01	-1.53	+0.13
G	Downstream of UHH/ Alexandra Stream crossing	0.00	+0.01	+0.08
H	Greville Road pond at inlet of 3000mm diameter culvert	-0.10	-0.23	-0.06
I	Rosedale Road/State Highway 1 (flood prone area)	-0.04	-0.15	0.00
J	Upstream of UHH/Alexandra Stream crossing	0.00	+0.05	+0.07

Figure 12 Reporting locations for pre- and post-development peak flows and water levels – Oteha Valley Catchment

A summary of the results is as follows:

- For the 2 year ARI event:
  - There is no increase in flood levels in the Oteha Stream (locations A, B and C in **Figure 12**);
  - There is a 10mm increase in flood levels at OF12 (location D in **Figure 12**;
  - There is a 300mm decrease in flood levels at the Meadowood Reserve (location E in **Figure 12**);
  - There is no change in flood levels immediately downstream of the Alexandra Stream/UHH crossing (location G in **Figure 12**);
  - There is a 40mm decrease at the Rosedale Road / SH1 intersection ponding area (location I in **Figure 12**); and
  - There is no increase in flood levels immediately upstream of the Alexandra Stream/UHH crossing (location J in **Figure 12**).
- For the 10 year ARI event:
  - There is no increase in flood levels in Oteha Stream (locations A, B and C in **Figure 12**);
  - There is a 40mm increase in flood levels at OF12 (location D in **Figure 12**);
  - There is a 420mm decrease in flood levels at the Meadowood Reserve (location E in **Figure 12**);
  - There is a 10mm increase in flood levels directly downstream of the Alexandra Stream/UHH crossing (location G in **Figure 12**). Closer inspection of the results (**Figure A2** in **Appendix L**) reveals that the flood level increases are localised about the discharge location.
  - There is a 150mm decrease at the Rosedale Road/SH1 intersection ponding area (location I in **Figure 12**); and
  - There is a 50mm increase in flood levels immediately upstream of the Alexandra Stream/UHH crossing (location J in **Figure 12**). This is consistent with the discharge location of the Rook Wetland into Alexandra Stream (upstream of the UHH crossing).
- For the 100 year ARI event:
  - There is no increase in flood levels in Oteha Stream (locations A, B and C in **Figure 12**);
  - There is a 40mm increase in flood levels at OF12 (location D in **Figure 12**)
  - There is a 460mm decrease in flood levels at the Meadowood Reserve (location E in **Figure 12**);
  - There is an increase in peak flood levels up to 80mm downstream of the Alexandra Stream/UHH crossing (location G in **Figure 12**). Closer inspection of the results (**Figure A3** in **Appendix L**) reveals that the increases do not extend beyond Paul Matthews Road Bridge. Note that there are no buildings identified as at risk of above floor flooding (floor within 500mm of the 100 year ARI MPD flood level) in this location;
  - There is a no increase at the Rosedale Road/SH 1 intersection ponding area (location I in **Figure 12**); and
  - There is a 70mm increase in flood levels immediately upstream of the Alexandra Stream/UHH crossing (location J in **Figure 12**). Closer inspection of the results (**Figure A3** in **Appendix L**) reveals that the increases do not extend beyond the Barbados Drive Bridge. There is a 30mm increase in peak flood level at the location where Alexandra Stream extends onto the property at 125 Unsworth Drive. Review of the consent documents for this property indicate that the lowest habitable floor level is still greater than 500mm above the post-development peak flood level in the 100 year ARI MPD event.

As outlined above, Rule E8.6.1(3) of the AUP provides that discharges should not result in or increase flooding of other properties in rainfall events up to the 10 year ARI event. Properties with existing flooding in the 10 year ARI event (MPD event) were identified from the AC flood maps (Appendix I in the Oteha Valley Catchment Stormwater Modelling Report, AC 2013).

As set out in **Table 11**, the modelling results indicate:

- There are peak flood level increases between 10mm to 70mm at seven of the properties which lie along the modified watercourse (Tait Place and Henry Rose Place) downstream of OF12 (refer location D in **Figure 12**). Note that these properties include the open channel itself within their property boundary. The 10 year ARI event is fully contained within the open channel in both the pre- and post-development scenarios. Therefore the effect of the small increase in peak flood level in the 2 and 10 year ARI events at these properties is considered to be insignificant;
- There is a 40mm increase in the 10 year ARI peak flood level at 125 Unsworth Drive (upstream of the Alexandra Stream crossing). The Alexandra Stream channel at this location is steeply incised and the flood extent is well-confined. Therefore the effect of the small increase in peak flood level in the 10 year ARI event at this property is considered to be insignificant;
- At the lower section of the Alexandra Stream main channel (75 Bush Road, 269 and R320 Rosedale Road), there are localised 10mm increases in the 2 and 10 year ARI peak flood level (no increases in the 2 year ARI event);
- There are no properties which do not currently flood that will flood as a result of the Project; and
- A number of properties show a slight reduction in peak flood level.

Table 11 Flood level differences at properties flooded in the 10 year ARI MPD event – Oteha Valley Catchment

Address	Predicted Peak Water Level (mRL)*			
	ARI (years)	Pre-Dev.	Post-Dev.	Difference (m)
66 Bush Rd	2	10.38	10.36	-0.02
	10	11.59	11.58	-0.01
75 Bush Road	2	12.07	12.06	-0.01
	10	12.96	12.96	0.00
3 Tait Pl	2	19.85	19.90	+0.05
	10	20.39	20.46	+0.07
5 Tait Pl	2	20.28	20.31	+0.03
	10	20.51	20.56	+0.05
7 Tait Pl	2	20.28	20.31	+0.03
	10	20.51	20.56	+0.05
9-11 Tait Pl	2	20.85	20.87	+0.02
	10	20.93	20.99	+0.06
10 Tawa Dr	2	21.21	21.21	0.00
	10	21.22	21.21	-0.01
12 Tawa Dr	2	21.63	21.62	-0.01
	10	21.71	21.69	-0.02
14 Tawa Dr	2	21.77	21.77	0.00
	10	21.84	21.84	0.00
7 Henry Rose Pl	2	18.76	18.78	+0.02
	10	19.16	19.18	+0.02
9 Henry Rose Pl	2	18.09	18.10	+0.01
	10	18.66	18.66	0.00
13 Henry Rose Pl	2	17.71	17.72	+0.01
	10	18.46	18.46	0.00

Address	Predicted Peak Water Level (mRL)*			
	ARI (years)	Pre-Dev.	Post-Dev.	Difference (m)
R12 Kristin Ln (Reserve)	2	14.30	14.27	-0.03
	10	15.41	15.40	-0.01
26 Kristin Ln (Reserve)	2	14.65	14.62	-0.03
	10	15.71	15.69	-0.02
R33 Clemows Ln (Reserve)	2	13.23	13.19	-0.04
	10	15.07	15.03	-0.04
269 Rosedale Road	2	15.86	15.86	0.00
	10	16.76	16.77	+0.01
R9 Vanderbilt Pde (Reserve)	2	7.88	7.87	-0.01
	10	9.35	9.33	-0.02
R44 Northwood Ave (Reserve)	2	7.99	7.97	-0.02
	10	9.49	9.48	-0.01
R320 Rosedale Rd (Reserve)	2	17.61	17.60	-0.01
	10	18.62	18.63	+0.01
125 Unsworth Dr[8]	2	30.44	30.44	0.00
	10	31.75	31.79	+0.04

*Note: Reported levels are computed water levels and do not include an allowance for freeboard.

Rule E8.6.1(3) of the AUP also provides that discharges should not result in or increase the inundation of buildings on other properties in events up to the 100 year ARI event. Properties which have existing above floor flooding (in the MPD scenario) were identified from the AC flood maps (Appendix I in the Oteha Valley Catchment Stormwater Modelling Report, AC 2013). The modelling results are set out in **Table 12**. There are no increases in predicted peak flood level in events up to the 100 year ARI event at properties at risk of above floor flooding.

[8] Although not constructed at the time of the Oteha stormwater report (AC, 2013), consent documents for the property at 125 Unsworth Drive indicate that the building habitable floor levels are all greater than 34.4mRL. This means the building floor levels are all greater than 500mm above the 100 year MPD flood level of 33.87mRL at this location (AC, 2013).

Table 12 Flood level differences at buildings with above floor flooding (as identified by AC, 2013) – Oteha Valley Catchment

Address	Floor Level Survey 2008 (mRL)			Predicted Peak Water Level (mRL)*			
	Residential Habitable	Business	Non-habitable	ARI (years)	Pre-Development	Post-Development	Difference (m)
6 Apollo Dr	-	46.87	-	2	47.67	47.67	0.00
				10	47.80	47.80	0.00
				100	47.89	47.89	0.00
8 Apollo Dr	-	46.25	-	2	45.82	45.82	0.00
				10	45.95	45.95	0.00
				100	46.23	46.23	0.00
14 Constellation Dr	-	48.26	-	2	47.98	47.98	0.00
				10	48.14	48.14	0.00
				100	48.26	48.26	0.00
22 Kristin Lane	16.57	-	16.39	2	14.65	14.62	-0.03
				10	15.71	15.69	-0.02
				100	16.37	16.36	-0.01
9 Pepperdine Place	11.25	-	11.25	2	8.84	8.82	-0.02
				10	10.19	10.18	-0.01
				100	11.09	11.08	-0.01
15 Vanderbilt Pde	9.71	-	9.70	2	7.18	7.16	-0.02
				10	8.64	8.63	-0.01
				100	9.54	9.54	0.00
17 Vanderbilt Pde	9.42	-	9.42	2	7.27	7.25	-0.02
				10	8.73	8.72	-0.01
				100	9.64	9.64	0.00
10 Notre Dame Way	16.62	-	16.49	2	12.34	12.34	0.00
				10	13.68	13.68	0.00

Address	Floor Level Survey 2008 (mRL)			Predicted Peak Water Level (mRL)*			
	Residential Habitable	Business	Non-habitable	ARI (years)	Pre-Development	Post-Development	Difference (m)
				100	16.99	16.99	0.00
117 Rosedale Rd	-	27.36	-	2	22.35	22.31	-0.04
				10	25.63	25.48	-0.15
				100	27.83	27.83	0.00
17 Te Hoe Grove	50.02	-	-	2	50.11	50.11	0.00
				10	50.37	50.37	0.00
				100	50.51	50.51	0.00

*Note: Reported levels are computed water levels and do not include an allowance for freeboard. Properties which have existing above floor flooding (in the MPD scenario) were identified from the AC flood maps (Appendix I in the Oteha Valley Catchment Stormwater Modelling Report, AC 2013).

A number of locations near the motorway show a reduction in peak flood levels due to the catchment now being captured by the motorway drainage infrastructure which directs runoff to the proposed wetlands.

There are also some localised peak flood level increases at locations not at risk of flooding, including:

- 100 year ARI event:
  - Upstream of the ARC Refuse Pond (removed) – the water level is contained within the pipe network and does not increase manhole surcharging or overland flow; and
  - Unsworth Road – a cut-off drain is provided at this location to direct overland flow to Alexandra Stream (impacts of this are captured in the flood modelling results).
- 10 year ARI event:
  - There are localised increases up to 20mm in peak flood level at Tawa Road, however these increases are contained within the pipe network and do not increase manhole surcharging or overland flow; and
  - There are localised increases up to 440mm in peak flood level at Saturn Place, however these increases are contained within the pipe network and do not increase manhole surcharging or overland flow.

Overall, the flood modelling results confirm that the flooding effects as a result of the project are being managed in the Oteha Valley catchment to an appropriate level through the proposed stormwater management design.

5.3.3.1.2 Lucas Creek Catchment

Figure 13 identifies the wetland discharge locations in the context of the overall catchment and the key reporting locations for pre- and post-development peak flows and water levels. **Table 13** summarises the predicted peak water level differences at the key reporting locations in **Figure 13** for the Lucas Creek catchment. **Figure A4** to **Figure A6** in **Appendix L** details the peak flow rates and levels at the key locations for the Lucas Creek catchment.

Table 13 Flood Modelling Results Summary – Predicted Peak Water Level Differences at Key Reporting Locations in the Lucas Creek Catchment (m)

Location (refer Figure 13)		2-year ARI	10-year ARI	100-year ARI
A	Lucas Creek at Dairy Flat Highway	-0.01	-0.01	0.00
B	Downstream of confluence of Lucas Creek and tributary at Appian Way	-0.01	0.00	0.00
C	Lucas Creek downstream of State Highway 1 (upstream of bus depot inflows)	-0.01	0.00	+0.01
D	Upstream of Albany Lake Reserve	-0.02	-0.27	-0.12

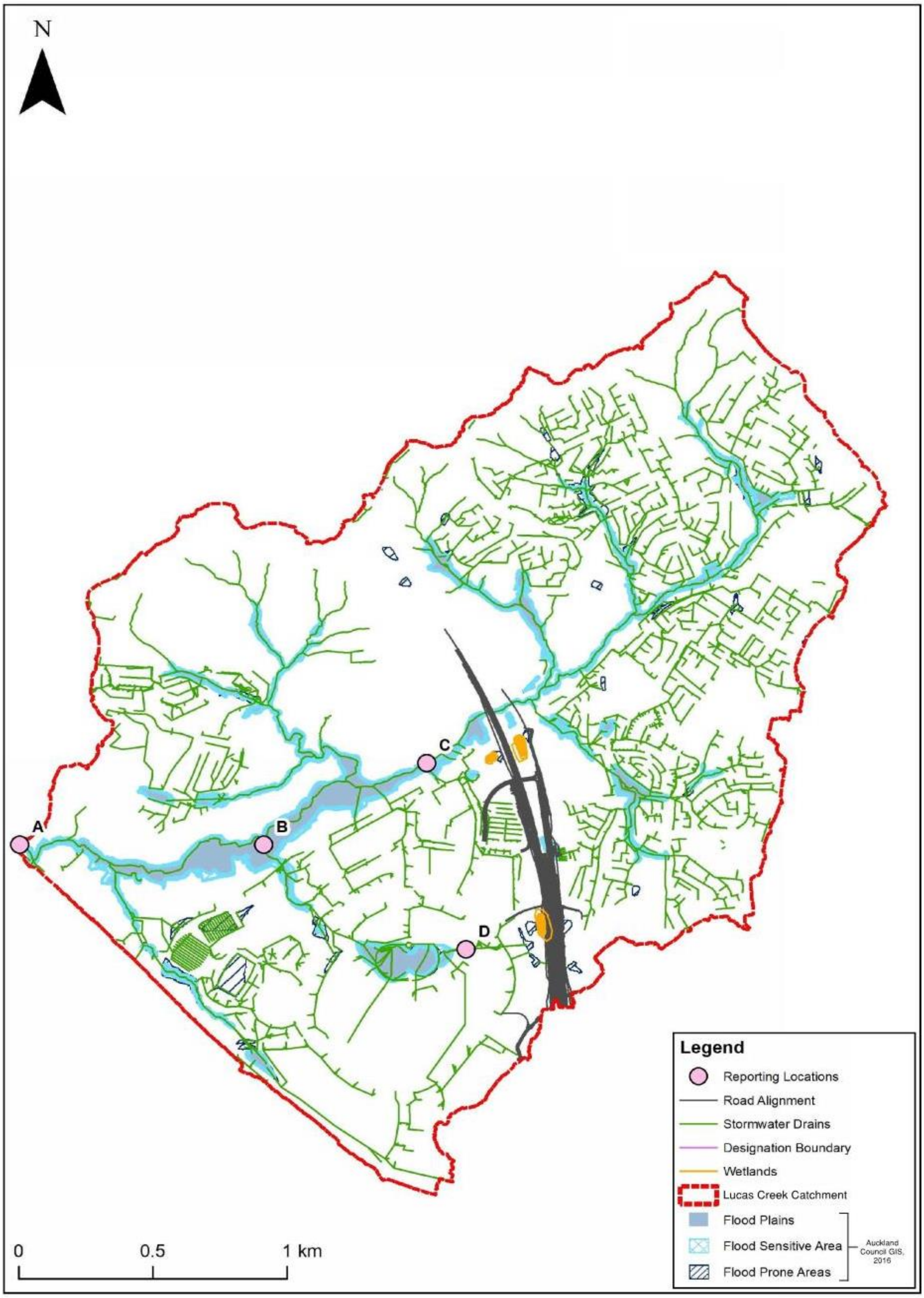
A summary of the results is as follows:

- In the 2 year ARI event:
  - There are negligible changes to the peak water level at the catchment outlet and the confluence of the tributary at Appian Way, as well as at Lucas Creek directly downstream of SH1 and upstream of Albany Lakes Reserve (locations A, B, C and D in **Figure 13**).
- In the 10 year ARI event:
  - There are negligible changes to the peak water level at the catchment outlet and the confluence of the tributary at Appian Way (locations A and B in **Figure 13**);

- There are negligible changes to peak water level at Lucas Creek directly downstream of SH1 (location C in **Figure 13**);
- There is a 270mm decrease in peak water level upstream of Albany Lakes Reserve (downstream of McClymonts Wetland discharge location – location D in **Figure 13**).

- In the 100 year ARI event:
  - There are negligible changes to peak discharge and peak water level at the catchment outlet and the confluence of the tributary at Appian Way (locations A and B in **Figure 13**);
  - There is a 10mm increase in peak water level at Lucas Creek directly downstream of SH1 (location C in **Figure 13**). Review of **Figure A6** (**Appendix L**) indicates that this is a very localised increase; and
  - There is a 120mm decrease in peak water level upstream of Albany Lakes Reserve (downstream of McClymonts Wetland discharge location – location D in **Figure 13**).

Figure 13 Reporting locations for pre- and post-development peak flows and water levels – Lucas Creek Catchment



Rule E8.6.1(3) of the AUP provides that discharges should not result in, or increase flooding, of other properties in rainfall events up to the 10 year ARI event. Properties with existing flooding in the 10 year ARI event are presented in Table 14 for comparison of the predicted peak water levels in the pre- and post-development scenarios. Results indicate that there are no increases in predicted peak flood levels for events up to the 10 year ARI at the properties identified with existing flooding, with the exception of a 10mm increase in the 10 year ARI event at one property (10 Mills Lane). The Project will not result in flooding to properties that are currently not flooded.

Note that there are no buildings which are at risk of above-floor flooding in the Lucas Creek catchment (as identified by NSCC (2009)), therefore an assessment of the increase of inundation of buildings up to the 100 year ARI event has not been carried out.

Table 14 Predicted peak flood level differences at properties flooded in the 10 year ARI MPD event – Lucas Creek Catchment

Address	Predicted Peak Water Level (mRL)			Difference (m)
	Event	Pre-Development	Post-Development	
10 Mills Ln	Q_2	13.54	13.52	-0.02
	Q_{10}	14.86	14.87	+0.01
14 Mills Ln	Q_2	14.26	14.24	-0.02
	Q_{10}	15.37	15.37	0.00
15 Gills Rd	Q_2	9.95	9.95	0.00
	Q_{10}	10.28	10.28	0.00
R20 Gills Rd	Q_2	8.64	8.63	-0.01
	Q_{10}	9.48	9.48	0.00
12 Oteha Valley Rd Ex.	Q_2	11.01	11.01	0.00
	Q_{10}	11.31	11.31	0.00
24 Oteha Valley Rd Ex.	Q_2	9.70	9.68	-0.02
	Q_{10}	10.69	10.69	0.00
85 Oteha Valley Rd	Q_2	35.94	35.94	0.00
	Q_{10}	36.38	36.38	0.00
97 Oteha Valley Rd	Q_2	35.32	35.32	0.00
	Q_{10}	35.61	35.61	0.00
129 Oteha Valley Rd	Q_2	30.13	30.13	0.00
	Q_{10}	30.72	30.72	0.00
131 Oteha Valley Rd	Q_2	29.97	29.97	0.00
	Q_{10}	30.55	30.55	0.00
135 Oteha Valley Rd	Q_2	28.97	28.97	0.00
	Q_{10}	29.47	29.47	0.00
137 Oteha Valley Rd	Q_2	28.97	28.97	0.00
	Q_{10}	29.47	29.47	0.00
141 Oteha Valley Rd	Q_2	28.17	28.17	0.00
	Q_{10}	28.94	28.93	-0.01

Address	Predicted Peak Water Level (mRL)			Difference (m)
	Event	Pre-Development	Post-Development	
143 Oteha Valley Rd	Q_2	28.00	28.00	0.00
	Q_{10}	28.76	28.75	-0.01
250 Oteha Valley Rd	Q_2	24.61	24.60	-0.01
	Q_{10}	24.68	24.68	0.00
R259 Oteha Valley Rd (Reserve)	Q_2	14.71	14.69	-0.02
	Q_{10}	15.62	15.62	0.00
R321 Oteha Valley Rd (Reserve)	Q_2	10.13	10.11	-0.02
	Q_{10}	11.18	11.17	-0.01
25 Fairview Ave	Q_2	31.59	31.59	0.00
	Q_{10}	33.04	33.04	0.00

Note: Reported levels are computed water levels and do not include an allowance for freeboard.

5.3.3.2 Hydrologic Regime

As discussed in **Section 5.3.2** in order to reduce peak flows caused by the increase in impervious area due to the Project, attenuation ponds are proposed. The ponds act to store the excess stormwater runoff volume and release it at a lower rate over a longer period of time. Therefore a change to the hydrologic regime of the receiving environment downstream of the stormwater discharge locations is expected. The significance of these changes to the hydrological regime depends on the discharge location in the context of the catchment (e.g. discharges into small tributaries in the upper catchment can be more significant than discharges into larger watercourses at the bottom of the catchment). The proposed discharge locations in the context of the overall catchment are shown in **Figure 10** and **Figure 11** for the Oteha Valley and Lucas Creek catchments, respectively.

The post-development changes to the flow hydrographs (discharge over time) at key reporting locations in the Oteha Valley and Lucas Creek catchments have been assessed for the 2, 10 and 100 year ARI events and are presented in the following sections. Hydrographs have been prepared for locations immediately downstream of the discharge locations as well as locations further downstream the catchment as set out below.

5.3.3.2.1 Oteha Valley Catchment

Hydrographs have been prepared for four locations in Oteha Valley (corresponding to the key reporting locations in **Figure 12**):

- Location C – Oteha Stream immediately downstream of discharges from the wetlands and dry ponds at the Greville Road interchange;
- Location D – Modified watercourse (tributary of Oteha Stream), downstream of Moro Wetland discharges;
- Location G – Alexandra Stream immediately downstream of Rook Wetland discharges; and
- Location B – Oteha Stream downstream of the Alexandra Stream and Oteha Stream confluence.

Results are presented in **Figure 14-17** at Location C, D, G and B respectively.

Figure 14 Comparison of Pre- and Post-Development Hydrograph, Oteha Stream Location C (refer Figure 12)

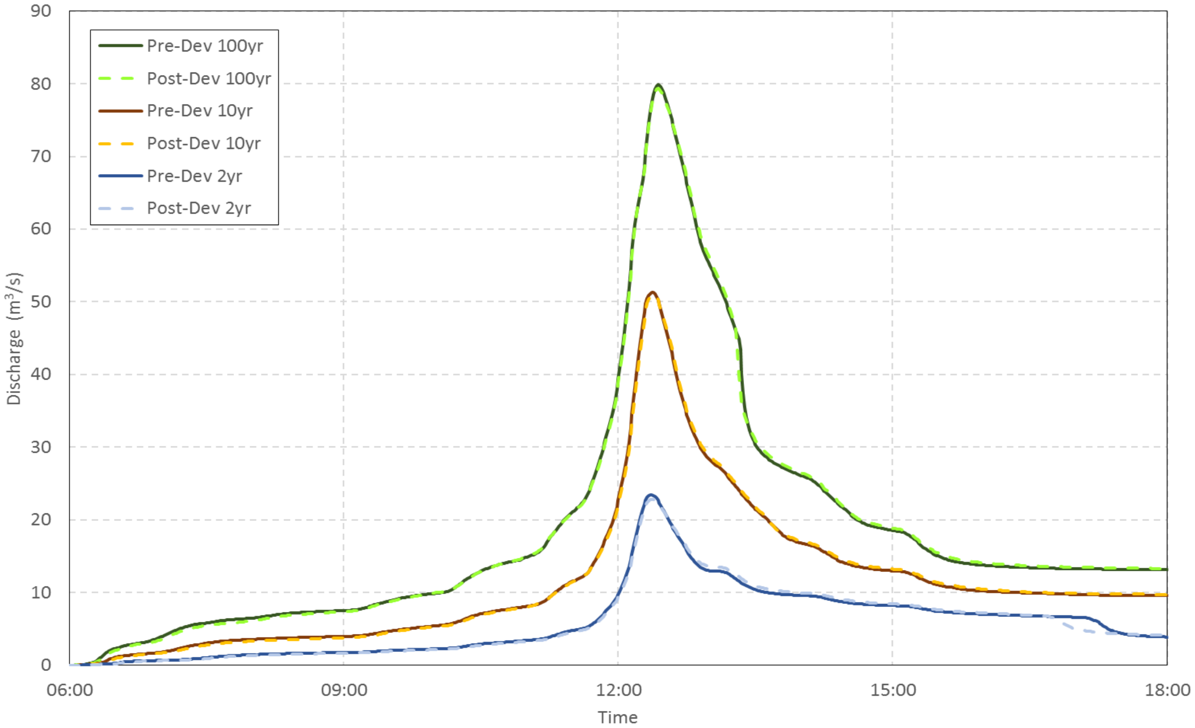


Figure 15 Comparison of Pre- and Post-Development Hydrograph, Modified Channel (tributary of Oteha Stream) Location D (refer Figure 12)

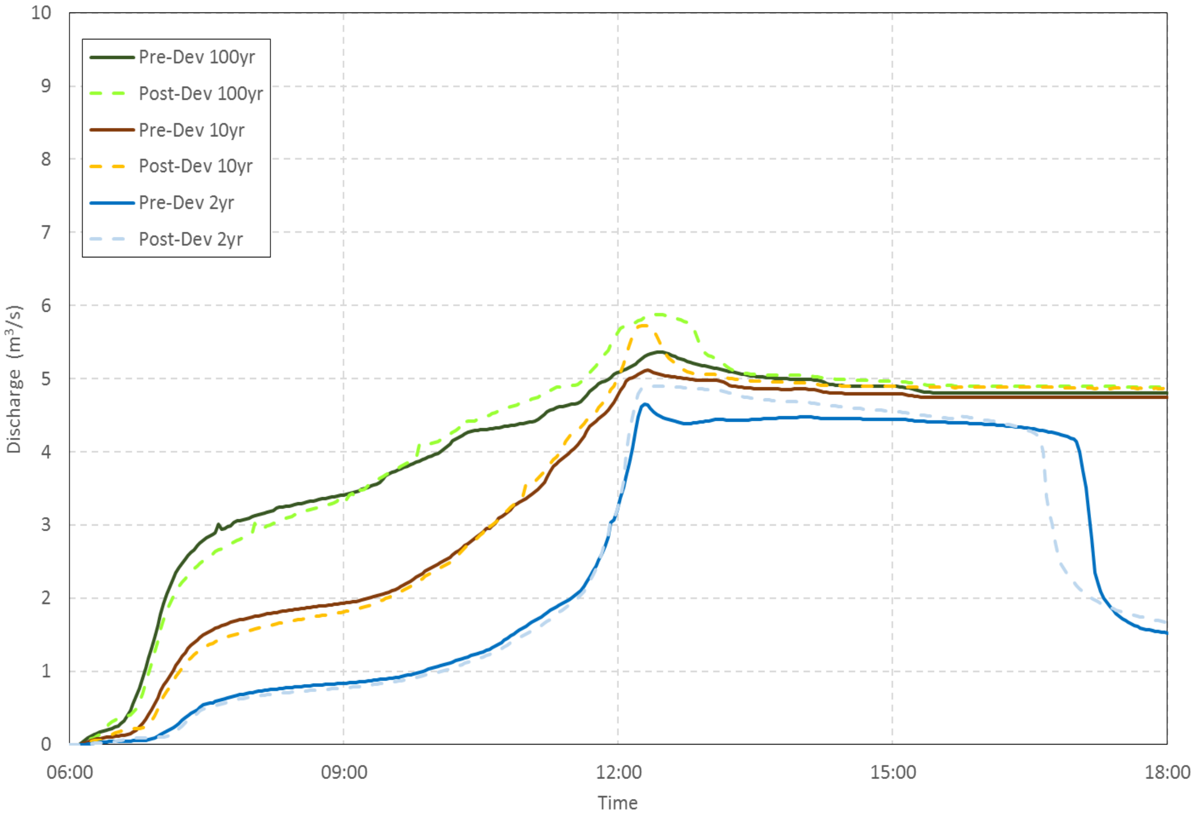


Figure 16 Comparison of Pre- and Post-Development Hydrograph, Alexandra Stream Location G (refer Figure 12)

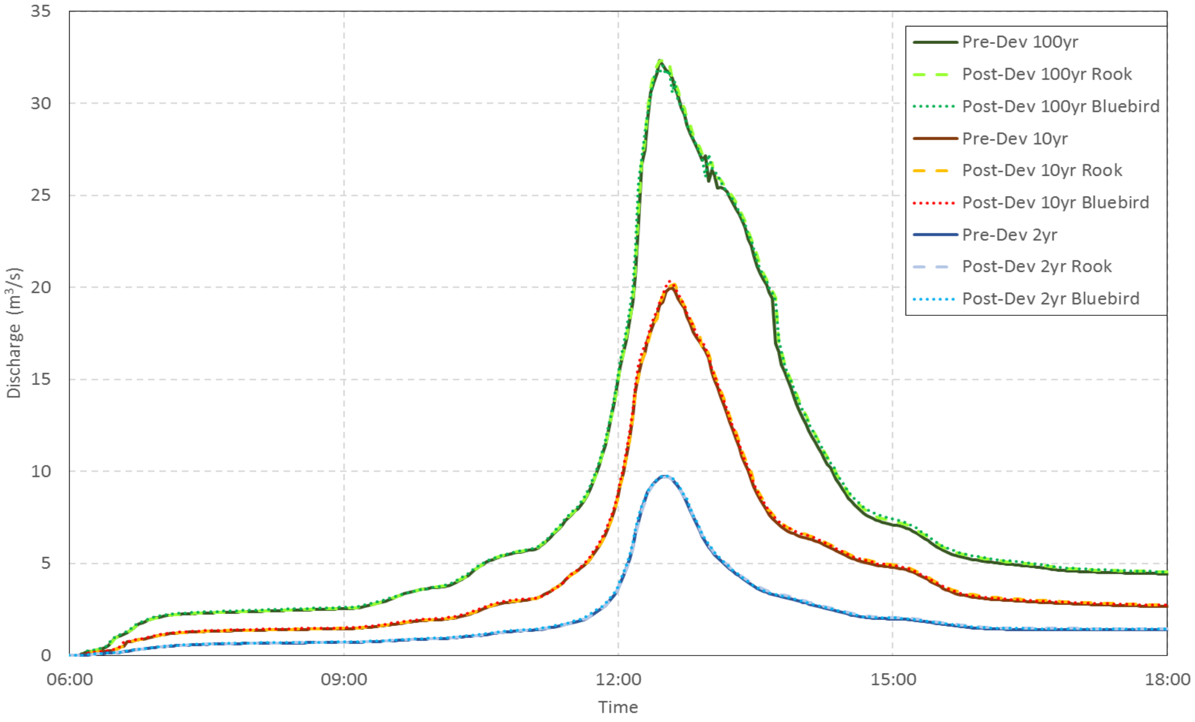
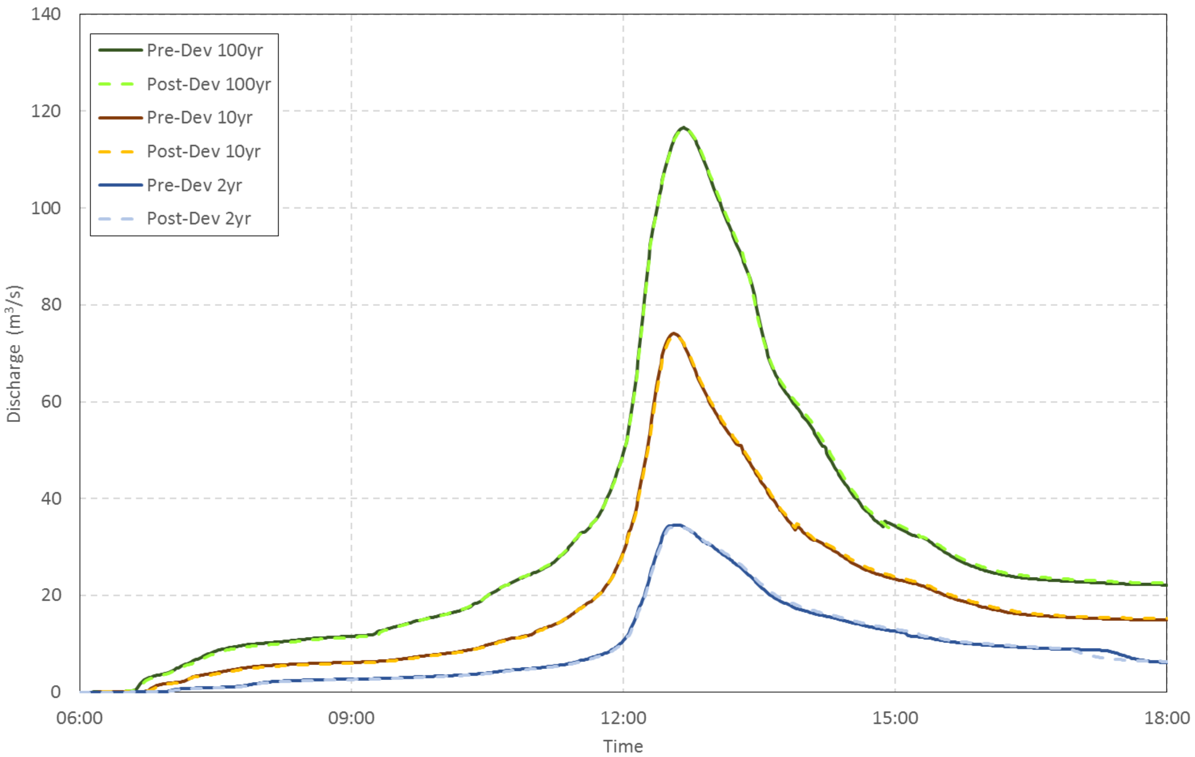


Figure 17 Comparison of Pre- and Post-Development Hydrograph, Oteha Stream Location B (refer Figure 12)



Review of the results indicates that the Project impact on the hydrological regime in the Oteha Valley catchment is negligible in Oteha Stream and Alexandra Stream, even immediately downstream of the Project discharge locations. The only location in the Oteha Valley catchment where the hydrological regime is impacted to a noticeable degree is downstream of Moro Wetland discharges at the outlet to the modified channel (OF12). At this location the peak discharge is increased but the impact to the hydrograph recession curve is considered negligible. Peak flow impacts at OF12 are discussed further in **Section 7.2**.

5.3.3.2.2 Lucas Creek Catchment

Hydrographs have been prepared for two locations in Lucas Creek catchment (corresponding to the key reporting locations in **Figure 13**):

- Location C – Lucas Creek downstream of SH1 and Oteha Valley East and West Wetlands discharges (upstream of bus depot inflows)
- Location B – Lucas Creek downstream of the confluence of Lucas Creek and the tributary at Appian Way

The hydrographs are contained in **Figure 18** and **Figure 19** for locations C and B, respectively.

Figure 18 Comparison of Pre- and Post-Development Hydrograph, Lucas Creek Location C (refer Figure 13)

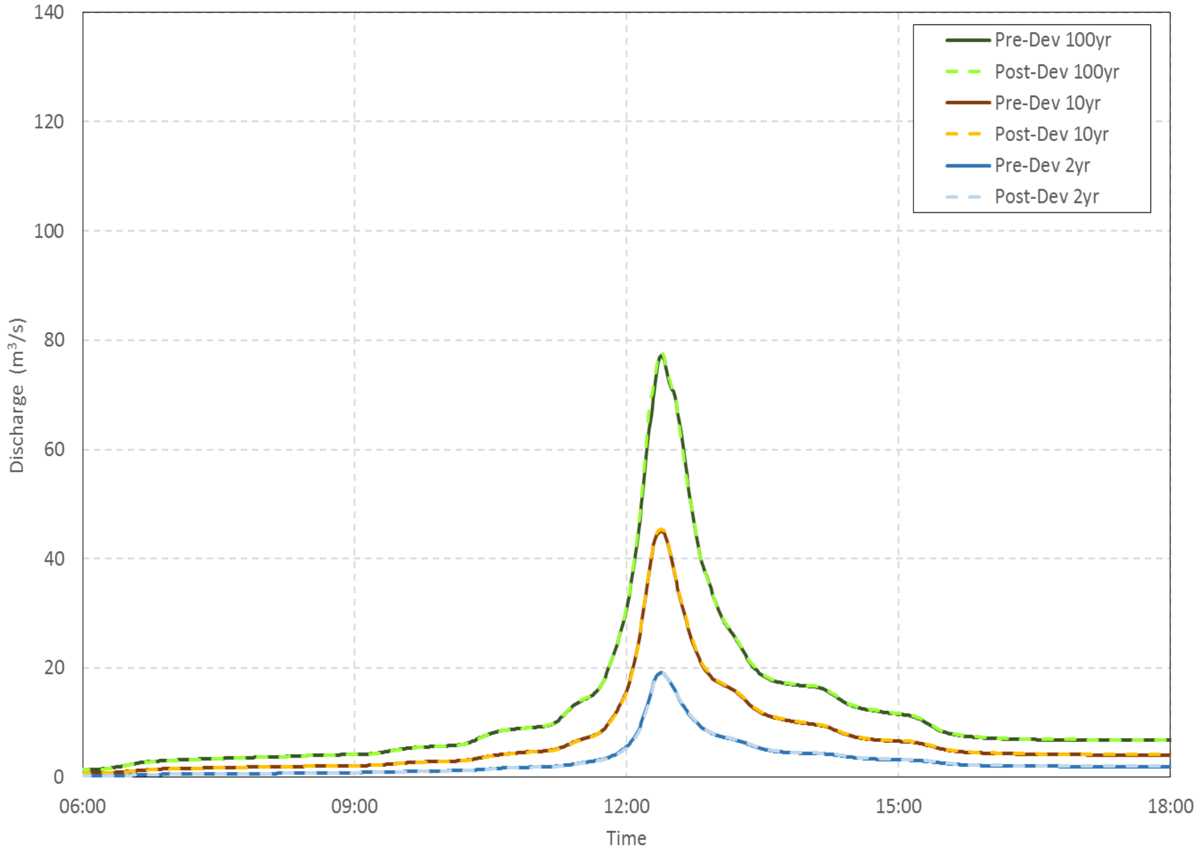
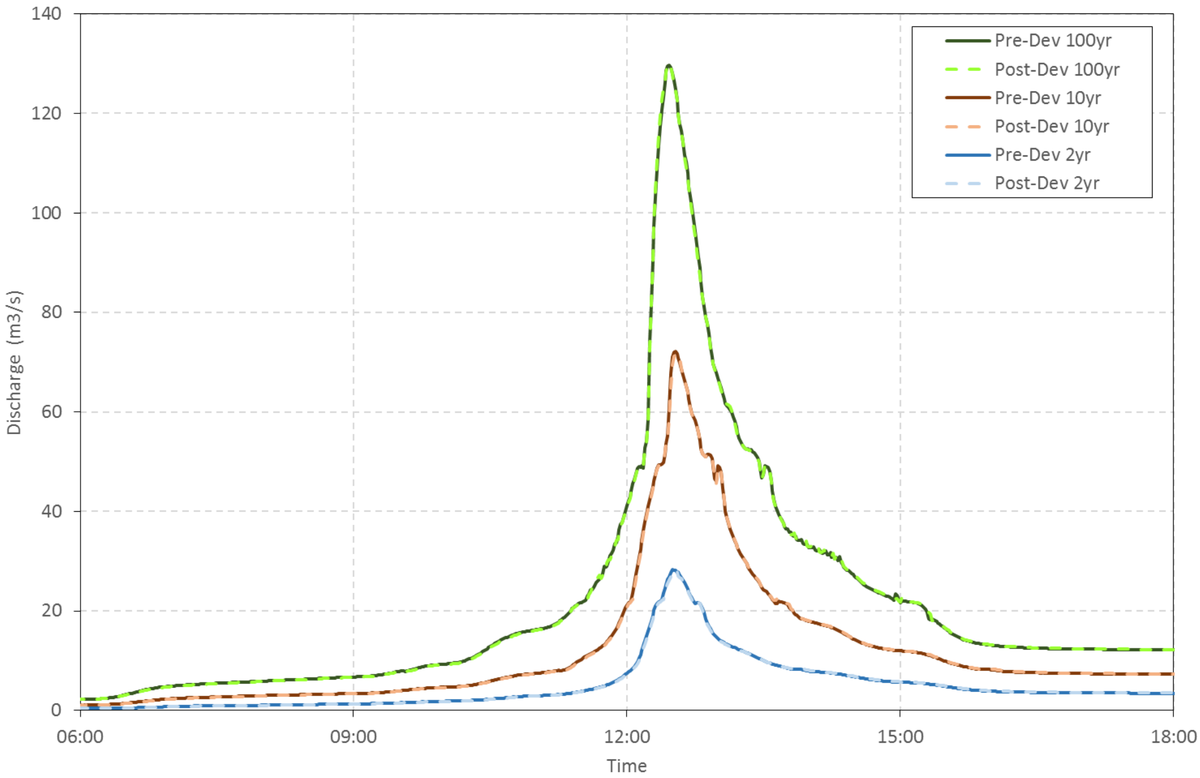


Figure 19 Comparison of Pre- and Post-Development Hydrograph, Lucas Creek Location B (refer Figure 13)



Review of the results indicates that the Project impact on the hydrological regime in Lucas Creek is negligible, even immediately downstream of the Project discharge locations.

5.3.4 Watercare Rosedale Wastewater Treatment Plant – Overflows into Ponds 1 & 2

Watercare has confirmed that any increased stormwater overflow into Pond 1 would have an adverse impact on the pond's wastewater treatment capacity. Watercare has also confirmed that Pond 2 is not required for treatment of wastewater.

The proposed stormwater management system to control overflow to the Watercare ponds include:

- Replacement of existing Constellation Pond and ARC Refuse Pond with a proposed high-level dry pond; and
- Attenuation of additional runoff from the proposed motorway with Caribbean Wetland.

Table 15 below summarises the pre and post-development stormwater overflows into the Watercare ponds.

The results indicate the proposed stormwater management system achieves a net reduction of total stormwater overflow into the Pond system when compared with the pre-development scenario for the 10 and 100 year ARI events. Further, a reduction of overflow has been achieved in Pond 1 for the 10 and 100 year ARI events. Note that there are no overflows into the ponds in the 2 year ARI event in either the pre- or post-development scenario.

The stormwater overflow to Pond 2 will be increased as a result of the Project. Since Pond 2 is not used or required for wastewater treatment function, the increased overflow is not expected to have an impact on the wastewater treatment capacity of the RWWTP.

In summary, the proposed stormwater management system for the Project will not adversely impact the wastewater treatment function of the RWWTP.

Table 15 Pre- and Post-Development Stormwater Overflows to Watercare Ponds 1 and 2

ARI (year)	Scenario	Pond 1 Peak Water Level (mRL)	Pond 2 Peak Water Level (mRL)	Overflow into Pond 1 (m^3)	Overflow into Pond 2 (m^3)	Total Overflows into Watercare Ponds (m^3)
2	Pre-Dev.	37.21	37.12	0	0	0
	Post-Dev.	37.21 (0.00)	37.11 (-0.01)	0	0	0
10	Pre-Dev.	37.37	37.35	24,900	10,700	35,500
	Post-Dev.	37.34 (-0.03)	37.33 (-0.02)	12,300 (-51%)	16,800 (+58%)	29,100 (-18%)
100	Pre-Dev.	37.85	38.43	79,500	92,600	172,000
	Post-Dev.	37.83 (-0.02)	38.57 (+0.14)	62,500 (-21%)	104,000 (+13%)	167,000 (-3%)

5.3.5 Watercare Rosedale Wastewater Treatment Plant – Existing Channel South of Pond 1

There is an existing artificial watercourse to the south of Pond 1 as described in **Section 2.4.4**. Works associated with discharge to this channel include the replacement of existing AC Constellation Pond and additional impervious areas which are proposed to be attenuated by the Caribbean Wetland. The existing channel is in good condition with no signs of erosion observed.

Due to the proposed changes, the velocity of peak flows in the channel has been compared between the pre-development and post-development scenario to ensure the Project does not result in unacceptable erosion potential to the channel.

It was found that the post-development velocity has not increased from pre-development velocity. The flow velocity in the channel is 0.3 m/s and 0.8 m/s in the detention and 100-year ARI event respectively. These velocities are less than the maximum velocity of 1.1m/s allowed under TP10 for channels with colloidal alluvial silts. Considering that the existing channel is flat, concrete lined, and well grassed, the post-development flow velocities are not expected to result in erosion issues.

5.4 Proposed Management of Existing Motorway Flood Risks

Table 16 summarises the proposed works for the management of the existing flood risks to the motorway (the existing risks are described in **Section 2.6**). **Figure 8** shows the location of the flood risk areas.

Table 16 Proposed works for management of existing motorway flood issues

Location (refer Figure 8)	Flood risk area	Project impacts	Mitigation Works proposed	Flooding Effects
M1	State Highway 1 Oteha Valley Road Interchange – Flooding on local road under motorway	None. Project works only include the proposed culvert CU-NEW-01 to be constructed under Oteha Valley Road.	None.	No change from existing.
M2	State Highway 1 Greville Road Interchange – Flooding on local road under motorway	None. Bridge abutments for proposed busway is to be constructed outside existing floodplain.	None.	No change from existing.
M3	State Highway 1 Rosedale Road floodplain adjacent to motorway	Proposed busway constructed over existing floodplain.	None.	100 year ARI event: 10mm increase (refer Section 5.3.3)
M4	State Highway 18 – Caribbean Drive Intersection	None. No works proposed upstream of the intersection.	Increase existing culvert size to reduce flooding.	Reduced flooding from existing (refer Section 5.3.3).
M5	State Highway 18 – Major overland flow path parallel to eastbound carriageway	Proposed SUP constructed over existing overland flow path.	Existing natural channel to be replaced with engineered channel of equivalent capacity.	No change to flood levels from existing. Channel velocities increase, which is mitigated by outfall protection.

5.5 Cross Drainage

5.5.1 Upstream Headwater Levels

The majority of the existing culverts within the Project area have adequate capacity and are proposed to be retained. Due to the motorway widening, many of the existing culverts require extension, on either the upstream or downstream end (or both).

Where existing culverts are proposed to be extended upstream, the extension generally is proposed to be at the same gradient as the existing culvert, which results in a higher culvert inlet invert level. The higher culvert invert level and reduced storage from motorway embankment widening may potentially result in increase to upstream headwater/ponding levels.

Table 17 summarises the assessment of upstream headwater levels for all existing culverts and the associated impacts. Refer to **Appendix G** for further details on culvert hydraulics with respect to the motorway freeboard design requirements.

Changes arising from culvert extensions/replacement have been incorporated into the post-development stormwater models to assess the cumulative impacts of the changes in the wider catchment, as discussed in **Section 5.3.3**.

Review of the results of the culvert headwater changes due to the Project indicates that there is one culvert location adversely affected by the Project. An increase of 70mm in the 100 year ARI event will occur at 125 Unsworth Drive, adjacent to the Alexandra Stream/UHH crossing (CU-EX-14).

Although not constructed at the time of the Oteha Stormwater Report (AC, 2013), consent documents for the property at 125 Unsworth Drive indicate that the building habitable floor levels are all greater than 34.4mRL. This means the building floor levels are all greater than 500mm above the 100 year MPD flood level of 33.87mRL at this location.

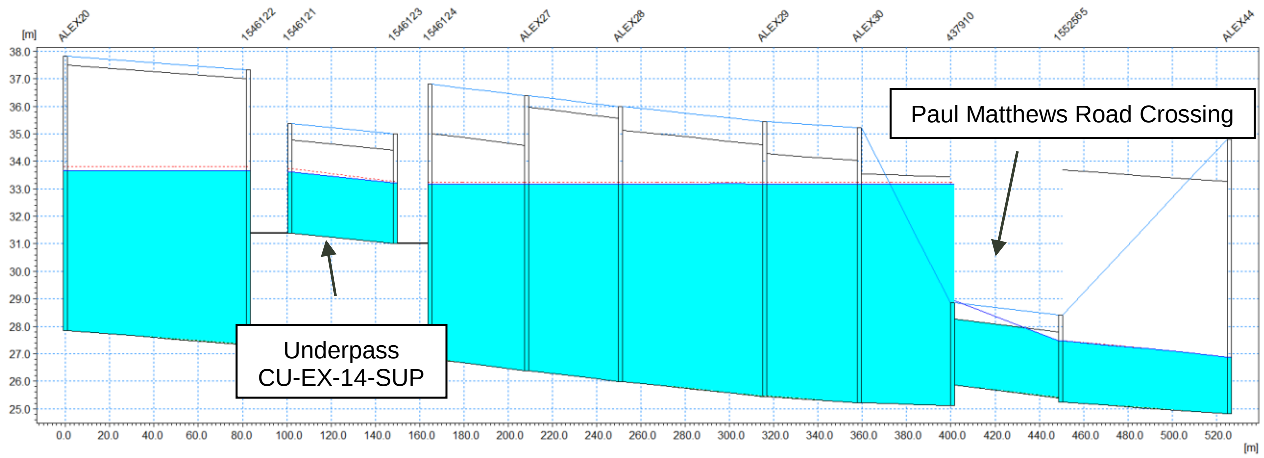
At the same location, the increase in headwater level causes an increase in the peak water level within the shared underpass itself (CU-EX-14-SUP) as follows:

- 60mm increase in the 100 year ARI event. Note that the pre-development flow depth in the underpass is 2400mm - at this depth the increase is considered to be insignificant (see further information below); and
- 40mm increase in the 10 year ARI event. Note that the pre-development flow depth in the underpass is 460mm.

Figure 20 shows the 100 year ARI hydraulic grade line in Alexandra Stream upstream and downstream of the UHH crossing (CU-EX-14 and CU-EX-14-SUP). **Figure 20** shows that the Paul Matthews Road crossing is undersized and is causing floodwater to pond upstream, extending to the UHH crossing. The ponding reaches a depth of approximately 2400mm in the shared underpass in the 100 year ARI event.

Although the Project causes a 60mm increase in the depth of flooding, the underpass is already flooded to such an extent as to make it unpassable. Works to the crossing at UHH such as increasing the culvert size or adding a new culvert will not reduce the flooding below a depth of 2400mm, as this depth is set by the ponding level caused by Paul Matthews Road crossing. Therefore, the Project impacts are considered to be insignificant in the context of the existing flooding at this location.

Figure 20 **Hydraulic Grade Line at Alexandra Stream/UHH Crossing, Shared Underpass (CU-EX-14-SUP), 100 year ARI MPD Event - Pre-development Scenario**



At all other locations, there are no properties adversely affected by increased headwater levels. The reasons for this include:

- Where culverts have been extended and upstream headwater levels increased, the headwater level is still contained within the stormwater network (no manhole surcharge in pre- or post-development scenarios);
- In some locations, culvert inflows are slightly reduced due reduced catchment areas as the motorway widening captures runoff and directs runoff to the motorway drainage network; and
- At locations whereof known upstream flooding affecting properties (e.g. Meadowood Reserve at CU-NEW-13B and CU-EX-15), increased culvert sizes and cut-off drains have been implemented to reduce upstream flooding.

Table 17 Post-Development Impacts of Culvert Headwater Levels (MPD Scenario)

Culvert	Project works potentially affecting US HW level	10-Year ARI Event			100-year ARI Event			Comment
		Headwater Level (mRL) Pre-Dev	Headwater Level (mRL) Post-Dev	Contained within Designation? (Y/N)	Headwater Level (mRL) Pre-Dev	Headwater Level (mRL) Post-Dev	Impact Existing Buildings? (Y/N)	
CU-NEW-01	New culvert crossing	-	26.65	Y	-	26.99	N	
CU-EX-02	Upstream extension	Headwater level contained within upstream manhole						
CU-EX-03	Upstream extension	Headwater level contained within upstream manhole						
CU-EX-04	None	-	-	-	-	-	-	-
CU-EX-05	None	-	-	-	-	-	-	-
CU-EX-06	Wetland/pond discharges into culvert	Headwater level contained within upstream manhole						
CU-EX-07	Embankment extends into existing ponded area	26.48	26.48	N	28.01	28.01	N	Although the upstream storage volume has reduced, the upstream flows have also reduced (catchment area captured by motorway drainage network)
CU-EX-08	None	-	-	-	-	-	-	-
CU-EX-09	None	-	-	-	-	-	-	-
CU-EX-10	Moro Pond removed and upstream end connected directly to pipe network.	Headwater level contained within upstream manhole						
CU-EX-11	None	-	-	-	-	-	-	-
CU-EX-12	ARC Refuse Pond removed, and upstream end connected directly to pipe network.	Headwater level contained within upstream manhole						
CU-NEW-13A	Replacement of culvert crossing	Headwater level contained within upstream manhole						

Culvert	Project works potentially affecting US HW level	10-Year ARI Event			100-year ARI Event			Comment
		Headwater Level (mRL) Pre-Dev	Headwater Level (mRL) Post-Dev	Contained within Designation? (Y/N)	Headwater Level (mRL) Pre-Dev	Headwater Level (mRL) Post-Dev	Impact Existing Buildings? (Y/N)	
CU-EX-13 (pre-dev) CU-NEW-13B (post-dev)	Replacement of culvert crossing	46.60	45.5	Y	49.65	48.76	N	Known flooding location at Meadowood Reserve
CU-EX-14	Receives excess flows from cut-off drain at CU-EX-15. Rook Wetland discharge location.	31.86	31.91	N	33.80	33.87	N	
CU-EX-14-SUP	Upstream extended 1.9m. Receives excess flows from cut-off drain at CU-EX-15. Rook Wetland discharge location.	31.86	31.91	N	33.80	33.87	N	Slight increases to upstream flood level.
CU-EX-15	Proposed cut-off drains to provide motorway freeboard	33.47	33.35	Y	36.55	35.91	N	Post-dev: Cut-off drain on southern side of UHH diverts flows overtopping road to Alexandra Stream (10 year ARI event and greater). Cut-off drain on northern side of UHH diverts excess flows to CU-EX-14 in 100 year ARI.
CU-EX-16	Proposed cut-off drains to provide motorway freeboard	Headwater level contained within upstream manhole						

5.5.2 Blockage Assessment

Preliminary blockage assessment of the cross drainage culverts is provided in **Table A3** in **Appendix G**. Results indicate that the following culverts may be affected by blockage of the inlet, and are likely to require some form of inlet blockage mitigation such as inlet oversizing or provision of a secondary inlet:

- CU-NEW-01;
- CU-EX-03; and
- CU-NEW-13B.

5.6 Overland Flow Paths

5.6.1 External Overland Flow Paths Approaching the State Highway

External catchment overland flow paths that approach the motorway corridor are proposed to be managed by cut-off drains.

Cut-off drains are open channels designed to intercept and convey external overland flows directed towards the Project area, from outside the Project area. Cut-off drains are proposed to be constructed using rectangular concrete channels, as this type of channel profile maximises hydraulic capacity for a given width. Cut-off drains for the Project have been preliminary sized to capture and convey the 100-year ARI event in the MPD scenario without overtopping.

Cut-off drains are typically proposed to discharge to the nearest motorway cross-culvert. This allows the proposed design to mimic the existing hydrological regime as much as possible to minimise impacts of cross-catchment flows.

Cut-off drains are an important element of the proposed stormwater management system as they act as a means to mitigate adverse flooding effects of private and public property associated with overland flow entering or running alongside the motorway.

Preliminary cut-off drain provisions proposed for the Project are shown on the Stormwater Layout Plans in **Appendix A**.

5.6.2 Overland Flow Paths on Local Roads

The Auckland Transport local road network are integral to the management of overland flow paths in Auckland Council stormwater catchments. The following local roads affected by the Project are identified as overland flow paths in the Auckland Council GIS system:

- Oteha Valley Road;
- McClymonts Road (partially);
- Greville Road;
- Rosedale Road (partially);
- Caribbean Drive; and
- Paul Matthews Road (partially).

In all the above cases, the local road is proposed to be either widened or realigned without decreasing its width, at similar grades. As such, the Project works do not adversely affect the capacity of local roads to act as overland flow paths. Due to the minimal works associated with local roads, velocities and depth changes are expected to be insignificant.

5.7 Assessment of Stormwater Quantity Effects

The potential impacts of the Project on stormwater quantity have been assessed and mitigation measures included in the design. A summary of the residual impacts of the Project is provided below.

There is an overall increase in the volume of stormwater runoff generated during rainfall events in the Oteha and Lucas Creek catchments due to the increase in impervious area.

Peak flow attenuation is provided for discharges to Oteha Stream (100-year ARI event) and to Alexandra Stream and Lucas Creek (10-year ARI event). The flow control devices mitigate the potential increase in downstream flood levels, with the following key residual impacts (post-mitigation):

- Significant reduction (300mm to 460mm) in peak flood levels at Meadowood Reserve, identified by AC as a flood prone location with regards to flooding impacting on a nearby kindergarten;
- Up to 80mm increase in peak flood levels for the 100 year ARI event in Alexandra Stream downstream of UHH crossing. The increases do not extend beyond the Paul Matthews Road Bridge. Note that there are no buildings identified as at risk of above floor flooding (floor within 500mm of the 100 year ARI MPD flood level) in this location; and
- Up to 70mm increase in peak flood level for the 100 year ARI event in Alexandra Stream immediately upstream of UHH crossing. The increase does not extend beyond the Barbados Drive Bridge and do not infringe on the 500mm freeboard for habitable floor levels at the property at 125 Unsworth Drive.

The key residual impacts of the Project on the hydrological regime are as follows:

- The only location where the hydrological regime is impacted to a noticeable degree is downstream of Moro Wetland discharges at the outlet to the modified channel. Rock armouring and lining to the channel bend will be installed as part of works separate to the Project in discussion with AC.

The key impacts of the Project on the RWWTP are as follows:

- A net reduction in total stormwater overflows into the Watercare Pond system; and
- An increase in stormwater overflows into Pond 2.

The Project results in the following key residual impacts on overland flow paths and upstream headwater levels at cross drainage infrastructure:

- There is a small increase (60mm in the 100 year ARI event) in peak water level within the shared underpass at the UHH/Alexandra Stream crossing. The increase in flooding does not impact the usability of the underpass, as it is already significantly under water in the existing case (2.4m depth of water in the 100 year ARI event within the underpass).

The Project will not result in flooding of properties that are currently not flooded, and a number of properties show a slight reduction in peak flood levels. Therefore, the stormwater quantity mitigation devices (including proposed flow attenuation devices, cutoff drains, culvert works, erosion protection at outfalls, etc.) will appropriately mitigate the potential surface water effects of the Project on the wider catchment.

6 Proposed Stormwater Quality Management

6.1 Overview

This section provides a description of the proposed stormwater quality management measures, including a quantified summary of stormwater quality management achieved over the Project.

The proposed stormwater design has aimed to achieve full treatment of stormwater runoff from new and existing HUR pavement areas within the Project area in accordance with TP10, where practicable. HUR pavement areas include motorway and ramps and local roads, where pavement areas have been widened or extended. HUR excludes the busway and shared-use paths in accordance with the AUP requirements (refer to **Section 6.2**).

The water quality treatment devices proposed for the Project have been designed using a comprehensive BPO approach, as discussed further in **Section 8** below.

6.2 AUP Requirements

Under the AUP, the stormwater provisions are broadly divided into stormwater runoff from impervious areas that are either:

- Diverted and directed to a stormwater network or the combined sewer network; or
- Diverted and discharged to land, water or the coastal marine area.

Given the nature of the works involved in the Project, two chapters of the AUP apply to the stormwater runoff within the Project area:

- Chapter E8 – Stormwater – discharge and diversion; and
- Chapter E9 - Stormwater quality - high contaminant generating car parks and HURs.

Chapter E8 – discharge and diversion

Chapter E8 contains the applicable rules for the diversion and discharge of stormwater runoff from impervious areas into or onto land or water or into the coastal marine area. These rules will apply to the whole the Project (including the Busway extension and proposed shared use path). A discharge consent is required under Chapter E8 of the AUP for discharges of stormwater runoff from within the Project area to the receiving environment.

Activity Table E8.4.1 Rule A1 provides that the diversion of stormwater runoff from a lawfully established impervious area directed into an authorised stormwater network that complies with Standard E8.6.2.1 is a permitted activity and will not require consent. Standard E8.6.2.1 requires that the impervious area was established as of the date of the rule becoming operative or that the diversion does not increase stormwater runoff to the combined sewer network (unless the increase is approved by the combined sewer network operator). The stormwater runoff that will discharge into AC's authorised stormwater network will not increase any stormwater runoff to the combined sewer network, and therefore the Project complies with Standard E8.6.2.1.

For the remainder of the stormwater that is not discharged into the AC owned stormwater network, a resource consent for a discretionary activity is required. This is because Rule E8.6.1(3) cannot be met. This rule has been discussed above and requires that the diversion and discharge must not result in or increase the flooding of other properties in rainfall events up to the 10 per cent annual exceedance probability (AEP) or inundation of buildings on other properties in events up to 1 per cent AEP. Flooding is likely to be increased at several properties downstream of the outfall points within the Lucas Creek and Oteha Valley catchments.

E9 – Stormwater quality – high contaminant generating roads

Chapter E9 contains the applicable rules for stormwater runoff the impervious areas of HUR, which is defined in the AUP as roads with volumes exceeding 5,000 vehicles per day. HURs are considered to generate stormwater runoff with higher levels of contaminants in comparison to local roads, and therefore require additional treatment prior to discharge.

A resource consent for a restricted discretionary activity is required under Activity Table E9.4.1(A9) because compliance cannot be achieved with Rule E9.6.2.2.

The relevant assessment criteria require that the impervious areas be treated in accordance with AC's standard TP10, whilst considering the BPO. The BPO requirements from Rule E9.8.2 are discussed in the Section 8.

Wetlands have been chosen as the preferred stormwater quality treatment device as they generally provide both water quality and quantity management functions.

6.3 Treatment Performance

The proposed stormwater management strategy has been developed to meet or exceed the treatment target of 75% TSS removal efficiency for all new HUR pavement areas as well as existing HUR pavement areas where practicable.

The Project's proposed stormwater management treatment will result in a decrease of contaminants entering the receiving environment compared to the existing situation.

The total stormwater treatment achieved by the Project is summarised in **Table 18**.

Table 18 Treatment Summary by Sub-Catchment

Sub-catchment	Outfall Location	Existing HUR Impervious Area (ha)	Increase in HUR Impervious Area (ha)	Existing HUR Impervious Area Treated to 75% TSS removal		Total HUR Impervious Area Treated to 75% TSS removal		
				Area (ha)	Existing treated / existing imp (%)	Area (ha)	Total treated / Total HUR (%)	New treated / New HUR (%)
Oteha Valley to McClymonts (OV2M)	Lucas Creek	3.32	0.13	3.32	100%	3.45	100%	100%
McClymonts to Spencer (M2S)	Albany Lakes Reserve	1.60	-0.01	1.48	93%	1.59	100%	No new HUR
Spencer to Rosedale (S2R)	Oteha Stream	7.69	1.73	3.52 (+3.88 at 55% TSS removal)	46%*	9.42	100%	342%
Rosedale to Constellation (R2C)	Modified watercourse north of Watercare Pond 1	3.70	2.84	1.89	51%	6.54	100%	164%
Constellation to Paul	Artificial watercourse	2.40	1.39	0.77	32%	3.37	89%	187%

Sub-catchment	Outfall Location	Existing HUR Impervious Area (ha)	Increase in HUR Impervious Area (ha)	Existing HUR Impervious Area Treated to 75% TSS removal		Total HUR Impervious Area Treated to 75% TSS removal		
				Area (ha)	Existing treated / existing imp (%)	Area (ha)	Total treated / Total HUR (%)	New treated / New HUR (%)
Matthews (C2PM)	south of Watercare Pond 1							
Paul Matthews to Albany Highway (PM2AH)	Alexandra Stream	2.36	2.19	0.00	0%	4.57	100%	209%
PROJECT TOTAL		**21.08**	**8.27**	**10.97**	**52%**	**28.94**	**99%**	**217%**

* This percentage excludes impervious areas that are treated to a standard less than 75% TSS removal

As shown in **Table 18**, treatment of all new HUR pavement areas has been provided as a minimum in each sub-catchment. In addition, treatment of existing impervious areas has been provided where it mixes with new HUR pavement areas that discharge to the same treatment device. In the R2C, C2PM and PM2AH catchments, significant existing impervious areas that are currently untreated are proposed to be treated. In OV2M and M2S, the majority of existing impervious area is already being treated, and therefore these areas provide limited opportunity to provide improvements to the existing scenario.

The following sub-sections provide an overview of the proposed stormwater management design with a particular focus on the treatment devices proposed to deliver outcomes that avoid, remedy or mitigate potential adverse environmental effects associated with stormwater runoff from the Project.

6.4 Stormwater Wetlands

Stormwater runoff quality and quantity management is provided by constructed wetlands where possible. AC TR2013/035 and TP10 have been used as the design guidelines for the design of wetlands. The design of stormwater wetlands satisfies the following requirements:

- Wetlands have been sized to treat the 90th percentile event in accordance with TR2013/035;
- A freeboard of 500mm from the maximum water level in wetlands to the road shoulder level is provided within all detention and attenuation wetlands;
- Internal and external batters of 1V:3H have been used for the design of wetlands – this has been increased from the 1V:5H recommended by TP10 due to space constraints;
- Safety benches 3m wide at 300mm below the permanent water surface have been provided in accordance with TP10;
- Detention of the 95th percentile and 90th percentile event (with release over 24 hours) are provided for wetlands within SMAF1 and SMAF2 areas respectively;
- Peak flow attenuation is provided for wetlands discharging to receiving environments that have existing flood issues or high risk of downstream flooding (all motorway sub-catchments within the Oteha Valley Stormwater Catchment);

- Maintenance access to wetlands are provided via local roads where possible. Suitable turning areas for maintenance vehicles and material laydown areas are also provided at the forebay;
- Emergency spillways are provided where practical as a mechanism for unrestricted discharge during extreme events. Where emergency spillways cannot be provided due to confined locations, the wetland outlet has been sized to provide for the 100-year ARI peak flow;
- Low flow wetland outlets can be manually shut to enable capture/isolation of spills on the motorway; and
- Existing wetlands that are not impacted by the proposed works are to be retained where possible.

All proposed wetlands provide detention to minimise stream erosion. Therefore, a 50% discount has been applied to the WQV for all wetlands in accordance with TP10. Table 19 below provides a summary of all wetlands, and the respective treatment performance achieved.

In sizing the WQV, detention, and attenuation volumes for the wetlands, the full contributing impervious and pervious areas have been included in the TP108 calculations[9] (refer to **Appendix K** for calculations relating to wetland sizing).

Table 19 includes only wetlands serving motorway catchments owned and managed by the NZ Transport Agency and does not include proposed replacement ponds that will be owned and operated by AC (refer to **Section 8.6.4** for details of proposed AC replacement ponds).

Table 19 Proposed Wetlands Summary

Wetland / Device	Location	Catch-ment	Total Catch-ment Area (ha)	HUR Area Treated to 75% TSS Removal (ha)	WQV with 50% discount (m^3)	Live volume (m^3)	Note for replacement of existing ponds
Oteha Valley East Wetland	State Highway 1-CH12030-SB	OV2M	1.73	0.74	480	1345	Includes WQV of 410m^3 from existing Alpurt A1 Pond 31
Oteha Valley West Wetland	State Highway 1-CH12030-NB	OV2M	0.43	0.43	150	495	No ponds replaced by this wetland.
McClymonts Wetland	State Highway 1-CH12720-NB	M2S	2.48	1.59	405	1225	Includes WQV of 325m^3 from existing Alpurt A1 Pond 32
Greville Wetland	State Highway 1-CH13670-NB	S2R	3.56	2.12	525	4420	Includes WQV of 115m^3 from existing Alpurt A1 Pond 33
Alpurt A1 Pond 34 (existing outlet to be modified)	State Highway 1-CH13930-NB	S2R	4.42	2.26	300	2520	Outlet modified for additional live volume.
Alpurt A1 Pond 35 (existing outlet to be modified)	State Highway 1-CH14050-NB	S2R	6.39	0.00	230	2800	Outlet modified for additional live volume.

[9] Discussed with Mark Iszard (AC Healthy Waters). Refer to consultation records in **Appendix F**.

Wetland / Device	Location	Catch-ment	Total Catch-ment Area (ha)	HUR Area Treated to 75% TSS Removal (ha)	WQV with 50% discount (m^3)	Live volume (m^3)	Note for replacement of existing ponds
Moro Wetland	State Highway 1-CH15100-NB	R2C	12.99	6.54	1195	4095	No ponds replaced by this wetland.
Caribbean Wetland	State Highway 18-CH720-EB	C2PM	5.25	3.09	470	2400	No ponds replaced by this wetland.
Rook Wetland	State Highway 18-CH1500-EB	PM2AH	4.60	2.85	355	2005	No ponds replaced by this wetland.

6.5 Planted Swales

In two sub-catchments where wetlands are not providing adequate treatment of new HUR pavement areas, swales are proposed as treatment devices and have been designed in accordance with TR2013/035.

The locations of the treatment swales is shown on **Figure 9**. The treatment swales are summarised in **Table 20** (refer to **Appendix M** for swale calculations).

Table 20 Proposed Treatment swales summary

Swale ID	Sub-Catchment	Impervious Area Treated (ha)	Swale Length (m)	Residence Time (min)	TSS Removal (%)
SW-S2R-1	S2R	1.02	160	20.7	>75%
SW-C2PM-1	C2PM	0.28	230	26.6*	>75%

* Note this is the average residence time (half of full residence time of 53.2 min) due to lateral inflow

The design of treatment swales provides for the following:

- Treatment swales achieve an average of 9 minutes residence time in accordance with TR2013/035. Due to the nature of swales being located longitudinally along the motorway, lateral inflows are considered acceptable in accordance with the NZ Transport Agency's Stormwater Treatment Standard;
- Front and back batters of 1V:3H have been used where swales are protected by traffic safety barriers. Front and back batters of 1V:4H and 1V:6H have been used for unprotected swales in accordance with Austroads;
- A minimum base width of 1.0m has been used for swales to allow establishment of plants and to achieve residence times;
- The maximum velocity in swales is 1.5 m/s and 0.8 m/s for the 10 year ARI event and Water Quality Flow (10mm/hr as per TR2013/035) respectively (in accordance with AC's TP10);
- All swales are planted to minimise long-term maintenance requirements. The final landscaping plan will be developed prior to construction, and will be coordinated with AC, AMA and Iwi; and
- Appropriate Manning's roughness coefficients are used for swale hydraulic calculations in accordance with the NZ Transport Agency's Stormwater Treatment Standard – 0.25 for planted swales for treatment.

Proposed swales are proposed to be planted with vegetation for this Project. Planted swales provide the following advantages:

- Reduced maintenance requirements (particularly advantageous where access to swales is often limited / restricted from the motorway);
- Improved gross pollutant capture;
- Increased channel bed stabilisation and erosion protection in swales;
- Hydraulic resistance (higher Manning's coefficient) to reduce flow velocity in swales;
- Improved removal of stormwater contaminants, via plant uptake;
- Enhanced ecological and visual benefit; and
- Promotion of evapotranspiration, which could reduce the volume of water discharged from the swale.

The main disadvantage with planted swales is that the establishment of vegetated swales is sometimes less successful than grassed swales. This may lead to high initial maintenance inputs. However, with appropriate plant selection and a comprehensive construction and maintenance plan (such as the AMA Operations and Maintenance Guideline 2009), plant establishment will be suitably monitored and managed as per other NZ Transport Agency projects.

Both grassed and planted swales are considered acceptable for treatment to the TP10 standard. Although the Project design proposes planted swales, there may be opportunities to utilise grassed swales for treatment during design development in the detailed design phase.

6.6 Stormwater Proprietary Devices

Stormwater treatment within the S2R catchment will be provided by a stormwater proprietary device (StormFilter or similar). The proposed proprietary device has been designed to provide treatment to meet 75% TSS removal for all existing and new HUR pavement areas discharging to the existing Alpurt A1 Pond 35. This pond is currently undersized and provides sub-standard treatment (appox. 55% TSS removal), but is proposed to be retained for stormwater quantity management for the Project.

A proprietary device is also proposed for treatment of the PM2AH catchment. This device will ensure 75% TSS removal for all remaining existing and new HUR pavement within this catchment that cannot be treated by the proposed Rook Wetland.

Table 21 provides a summary of the proposed proprietary devices for the Project (refer to **Appendix N** for calculations and preliminary drawings of the proposed proprietary devices).

Table 21 Proposed proprietary device

Proprietary Device ID	Sub-Catchment	Impervious Area Treated (ha)	TSS Removal (%)
SF-S2R-1	S2R	4.02	75%
SF-PM2AH-1	PM2AH	1.72	75%

There are two existing propriety treatment devices within the Project area that will be removed due to the earthworks proposed as part of the motorway widening at CH15000 and CH15800 on SH1. The treatment performance of these two proprietary devices are replaced by proposed wetlands.

6.7 Proposed Local Road Stormwater Management

The Project includes realignment works in relation to the following local roads:

- Busway access ramp to Albany Bus Station;

- McClymonts Road Bridge;
- Greville Road;
- Rosedale Road;
- Caribbean Drive; and
- Paul Matthews Road.

Treatment, detention and attenuation are not proposed for the re-alignment of local roads that do not increase existing impervious areas. **Table 22** summarises the stormwater management works proposed for each of the above local roads.

Table 22 Stormwater Management of Local Roads

Local Road	Stormwater Management Proposed
Busway access ramp to Albany Bus Station	No increase to existing impervious areas. No stormwater management proposed. Upgrades to existing reticulation may be required as flows are diverted to further upstream in Albany Bus Station piped system.
McClymonts Road Bridge	Sub-catchment from Medallion Drive to west of McClymonts Bridge to discharge to McClymonts wetland for treatment, detention and attenuation.
Greville Road	Currently discharges to Alpurt A1 Pond 34 and 35 for treatment, detention and peak flow attenuation in existing scenario. Modified Greville Road discharges to the same ponds. The changes to impervious areas on Greville Road are captured within HUR calculations above. Refer to Section 2.4.2 for details on treatment performance of these ponds.
Rosedale Road	No increase to existing impervious areas. No stormwater management proposed.
Caribbean Drive	No increase to existing impervious areas. No stormwater management proposed.
Paul Matthews Road	No increase to existing impervious areas. No stormwater management proposed.

6.8 Summary of Proposed Stormwater Management System

The potential effects of stormwater contaminants from within the Project area on the downstream receiving environment will be mitigated by treatment devices designed in accordance with the AUP requirements, AC's TP10 and TR2013/035.

A treatment train approach to manage stormwater runoff from new and existing impervious areas across the Project has been provided, including dedicated at source catchpit devices and planted swales for capture and conveyance of stormwater runoff, and planted wetlands as the primary treatment means for treating stormwater runoff from the Project.

There is approximately 8.3ha of additional impervious surface classified as HURs resulting from the Project. The proposed stormwater management system will result in the treatment to 75% TSS removal on a long-term average basis for approximately 99% of all HUR pavement areas within the Project area. This is a significant increase from the existing situation where 52% is being treated.

Improved treatment performance is achieved through provision of water quality treatment of existing motorway areas that currently have no dedicated treatment facility.

7 Stormwater Outfalls

7.1 Overview

There are a number of new and modified stormwater outfalls proposed, and existing outfalls to be retained as part of the Project.

All proposed pipe outfalls discharge to the receiving environment via precast wing-wall structures, in accordance with the NZ Transport Agency stormwater specification for outfall pipes of 375mm in diameter or larger. Erosion protection measures at outfalls will include:

- Rip-rap aprons and rip-rap basins;
- Designed for the 100-year ARI event; and
- Proposed within the designation.

Existing outfalls are to be generally retained without modification. Peak discharges at existing outfalls are unchanged, with the exception of OF12 which is discussed further in the sub-section below.

New outfalls are to be provided at the following locations:

- New proposed culvert outlets to receiving environment;
- Wetland outlets to receiving environment;
- Cut-off drain outlets to receiving environment; and
- Network drainage outlets to receiving environment.

New and existing outfalls from the Project to the receiving environment are shown on **Figure 9** in **Section 4.1**. New outfalls are proposed to discharge into Lucas Creek, Oteha Stream and Alexandra Stream. The volume of discharge at these locations are shown in **Table 23**.

Table 23 Increased Volumes of New Outfalls

Discharge Location	Scenario	WQ Event Volume (m^3)	2-Year ARI Volume (m^3)	10-Year ARI Volume (m^3)	100-Year ARI Volume (m^3)
Lucas Creek	Pre-Dev	813	3,742	7,920	13,417
	Post-Dev	1,011 (+198)	4,226 (+484)	8,564 (+644)	14,160 (+743)
Oteha Stream	Pre-Dev	2,031	10,172	22,271	38,406
	Post-Dev	2,816 (+785)	12,099 (+1,927)	24,837 (+2,566)	41,368 (+2,962)
Alexandra Stream	Pre-Dev	682	3,721	8,396	14,700
	Post-Dev	1,130 (+448)	4,819 (+1,098)	9,858 (+1,462)	16,388 (+1,688)

Refer to **Appendix O** for details of the existing and proposed outfalls. During detailed design, additional outfalls for network drainage systems may be required. New discharges to AC's stormwater network will be applied for in accordance with AC's Engineering Approval process.

7.2 Existing Outfall Structure OF12

This is an existing Auckland Council asset that services discharges from the Oteha Valley catchments upstream of (diverted around) the Watercare Ponds. This outfall has been assessed in detail because the discharge will be increased at this location as a result of the Project.

As detailed in **Section 5.3.3**, the Project causes small increases in discharge at the outlet of the 1200mm diameter pipe referenced as OF12 (location D in **Figure 12**). Increases in discharge are approximately 2%, 10% and 11% in the 2, 10 and 100 year ARI events, respectively.

The outfall structure at this location consists of a concrete apron with baffles, as shown in **Figure 21**. The outfall is located within the emergency spillway of the Watercare RWWTP Pond 1, and has significant reinforcing of the embankment structure adjacent to, and surrounding the outfall. Site inspection has been undertaken (refer **Figure 21**), and the following is noted:

- The headwall and baffles appear to be solid;
- The structure appears to be constructed in rock;
- The AC GIS asset data indicates the outfall structure has been in operation for 55 years (installed in 1961);
- Almost immediately downstream of the outfall, there is a sharp bend in the watercourse;
- The watercourse downstream of the bend is well lined with streambank erosion protection matting;
- There are significant established trees downstream of the outfall; and
- There is some localised signs of minor erosion at the outside bend directly opposite the outfall.

Figure 21 **Existing erosion projection at Outfall Structure OF12, and armoured modified watercourse downstream of OF12.**

To understand the erosion potential, the post-development flow velocity in the channel has been compared to the pre-development flow velocity during the detention storm event (26mm/24hr). It was found that the post-development peak flow velocity is identical to the pre-development velocity of 1.2m/s. This velocity is less than the maximum velocity of 1.5m/s allowed in TP10 for unlined channels (cobble/shingle type). Considering that the existing channel is lined, a flow velocity of 1.2m/s is not expected to result in erosion issues.

Based on the above, the outfall structure and watercourse downstream of the bend are considered to be stable and capable of operating with no adverse effects due to the small increases in discharge. However, the left bank of the first right-hand bend directly downstream of the outfall is not armoured and shows existing signs of minor erosion. Small increases in velocities are expected during extreme storm events (<5%), which may slightly increase the existing erosion at this location.

Rock armouring and lining to the channel bend will be installed as part of works separate to the Project in discussion with AC.

7.3 Assessment of effects relating to stormwater outfalls

Excessive energy at stormwater outfall locations from pipes/culverts discharging into natural waterways/open channels have the potential to cause bed scour and bank erosion if not mitigated properly. The potential stream erosion impacts of the Project will be mitigated through the provision of extended detention in proposed wetlands, as well as erosion protection measures at new outfalls or outfalls affected by the Project. Wetland outfalls will incorporate erosion protection measures to minimise bed scour and bank erosion in the receiving waterway. Typically, erosion protection at outfalls is provided by an energy dissipation device and/or rock aprons. The location of outfalls will be carefully selected to avoid discharging over steep vertical banks to reduce the likelihood of bank erosion. These solutions are standard practice and will be addressed during detailed design.

The adverse effect of increased erosion potential to stream banks due to increased peak flows and velocities from the Project will be appropriately mitigated by proposed wetlands, riprap aprons and basins at outfalls, in accordance with TP10. Any increases in stream bank erosion potential are considered to be insignificant as a result of the mitigation measures proposed.

8 Best Practical Option Assessment

8.1 Overview

The options considered for stormwater treatment, detention and attenuation for the Project are set out below with a summary of the advantages and disadvantages of each option considered.

The BPO approach is used to determine the most appropriate treatment device and water quantity control measures for the Project as required by the AUP.

The RMA defines the BPO as:

> *The best method for preventing or minimising the adverse effects on the environment, having regard, among other things to –*
>
> *(a) The nature of the discharge or emission and the sensitivity of the receiving environment to adverse effects;*
>
> *(b) The financial implications and effects on the environment of that option when compared with other options; and*
>
> *(c) The current state of technical knowledge and the likelihood that the option can be successfully applied.*

In relation to water quality, the assessment criteria in E9.8.2 of the AUP requires consideration of whether the stormwater management device(s) proposed is the best practicable alternative and whether the potential adverse effects (including cumulative effects) are appropriately minimised or mitigated, taking into consideration all of the following:

- The nature of the contaminants and associated discharge to the receiving environment;
- The sensitivity of the receiving environment, including coastal waters, and its susceptibility to the adverse effects of the contaminants;
- The extent to which stormwater contaminants from the site contribute to incremental and cumulative adverse effects on receiving environments including adverse effects on biodiversity, community and Mana Whenua uses and values;
- Whether it is practicable to reduce existing adverse effects including site and operational constraints; and
- Whether stormwater contaminants are managed entirely onsite or whether there is an authorised stormwater management device or system in the catchment that is designed and sized to accommodate the stormwater runoff and contaminant loads and achieve appropriate mitigation.

In relation to the water quantity issues, the policies in E10.8.2 are relevant (as set out in **Section 5.2** above). These matters have all been considered in determining the BPO for stormwater management for the Project.

The summary below sets out the BPO for the sub-catchments contributing to each of the main discharge locations. The water quality, detention, retention and peak flow attenuation requirements and how these are achieved (where they are required) for the sub-catchments are described in the following sections.

8.2 Stormwater Management Device Selection

The BPO approach was used to determine the most appropriate stormwater treatment devices from the options in TP10 and the NZ Transport Agency Stormwater Treatment Standard (2010). **Table 24** provides a brief description of the merits and constraints of different treatment devices which inform the choice of the BPO. **Appendix P1** contains further details on each type of stormwater management device.

Table 24 Stormwater Management Device Comparison

Stormwater Management Device	Advantages	Disadvantages	BPO for Project (Y/N)
Swales	Effective devices for water quality treatment Can be used to provide informal pre-treatment before discharging to wetlands or other dedicated other treatment devices	Requires a considerable length to function for treatment Do not provide adequate volume storage for peak flow attenuation	Yes
Filter Strips	Sheet flow – potential for erosion and scour due to the discharge is therefore reduced Effective at TSS concentration reduction, removal of Cu, Pb and Zn	Do not provide quantity control Require a large area for the device immediately adjacent to the pavement surface (i.e. along the side of the carriageway) Not suitable for areas with moderate to steep slopes and areas where the area adjacent to the motorway is constrained	No
Rain Gardens	Treat stormwater runoff by filtration, infiltration, adsorption and biological uptake Discharge flow over a relatively large area, and therefore the potential of erosion and scour due to the discharge is reduced	A large footprint is required High maintenance costs No quantity control High sediment loads lead to clogging Not suited to longitudinal, constrained environments such as motorways where a higher level of traffic management for maintenance activities is required	No
Proprietary Filter Cartridges	Stormwater360 StormFilter are AC approved for water quality treatment for high traffic load applications Targeted removal of metals and hydrocarbons Small space required for the device	Not suitable when attenuation is required High maintenance requirement and underground maintenance required	Yes
Sand Filters	Effective at removal of hydrocarbons Effective at removal of finer sediments	Suited for small catchment areas Hydraulic head requirement through sand filters is larger than that through the proprietary filter devices Sand filters require a large physical space and more space for maintenance activities Do not provide any water quality control Prone to clogging and require maintenance on a more frequent basis than a practice such as wetlands	No

Stormwater Management Device	Advantages	Disadvantages	BPO for Project (Y/N)
Dry Stormwater Management Ponds	Provides greater detention and attenuation volumes for the same foot print than wet ponds and wetlands	No water quality treatment function	Yes
Wet Stormwater Management Ponds	Provides water quality and quantity control Smaller footprint than wetlands Low maintenance	Deeper permanent water depth than wetlands – increased safety risk Warming of water temperature due to pond surface area	Yes
Wetlands	Provides water quality and quantity control Low maintenance Wetland plants filtering, absorption and uptake Visual amenity and are a better habitat for wildlife	Larger footprint than wet ponds	Yes

8.3 Location Selection

The location of devices was selected based on the following factors:

- Land constraints
  - Minimise footprint of stormwater treatment assets where possible;
  - Locate within existing motorway designation where possible to minimise the impact on third party land owners;
  - Where not possible to locate devices within the existing motorway designation, land acquisition from AC or other crown/government organisations has been considered; and
  - Land acquisition from third party land owners for stormwater devices was only considered where all other options had been exhausted.
- Hydraulic constraints
  - Locations near low points and discharge points (streams, etc.) along the motorway were preferred. This maximises the impervious area managed by one centralised device, which is preferable from a long-term maintenance perspective.
- Floodplain
  - Treatment and attenuation devices were located outside floodplains where possible to avoid impacts on existing flood levels.
- Devices owned by external parties
  - Stormwater runoff from the State Highway are proposed to discharge to wetlands owned and operated by the NZ Transport Agency for stormwater management. The Project avoids discharging stormwater from the Stage Highway to AC stormwater management devices.

8.4 Environmental considerations

In considering the BPO, regard has been had to the nature of the discharge and the sensitivity of the receiving environment as set out in the Assessment of Freshwater Ecological Effects. The following factors have been considered:

- The nature of the receiving environment; and
- The potential effects on aquatic life.

The need to provide for fish passage has also been considered. The Assessment of Freshwater Ecological Effects concludes that there is no upstream native fish habitat (largely because the catchment is fully urbanised and culverted); there are significant barriers downstream, including vertical manholes; and there is currently only very poor quality habitat for native fish (exposed, concrete drains). On this basis, the stormwater management system does not provide for fish passage.

8.5 BPO by Catchment

The BPO for each motorway catchment is summarised in this section. The device and location selection are based on the philosophy discussed in **Section 8.1**.

Appendix P2 contains a more detailed analysis of the alternatives considered.

8.5.1 Oteha Valley to McClymonts (OV2M) Catchment

The proposed stormwater management for this sub-catchment is summarised in **Table 25**.

Table 25 OV2M Stormwater Management Proposed

Stormwater Management	Yes/No
Water quality	Yes – 75% TSS removal (100% of total HUR to be treated)
Detention	Yes – SMAF1
Retention	No
Peak Flow Attenuation	Yes – Q_2, Q_{10}

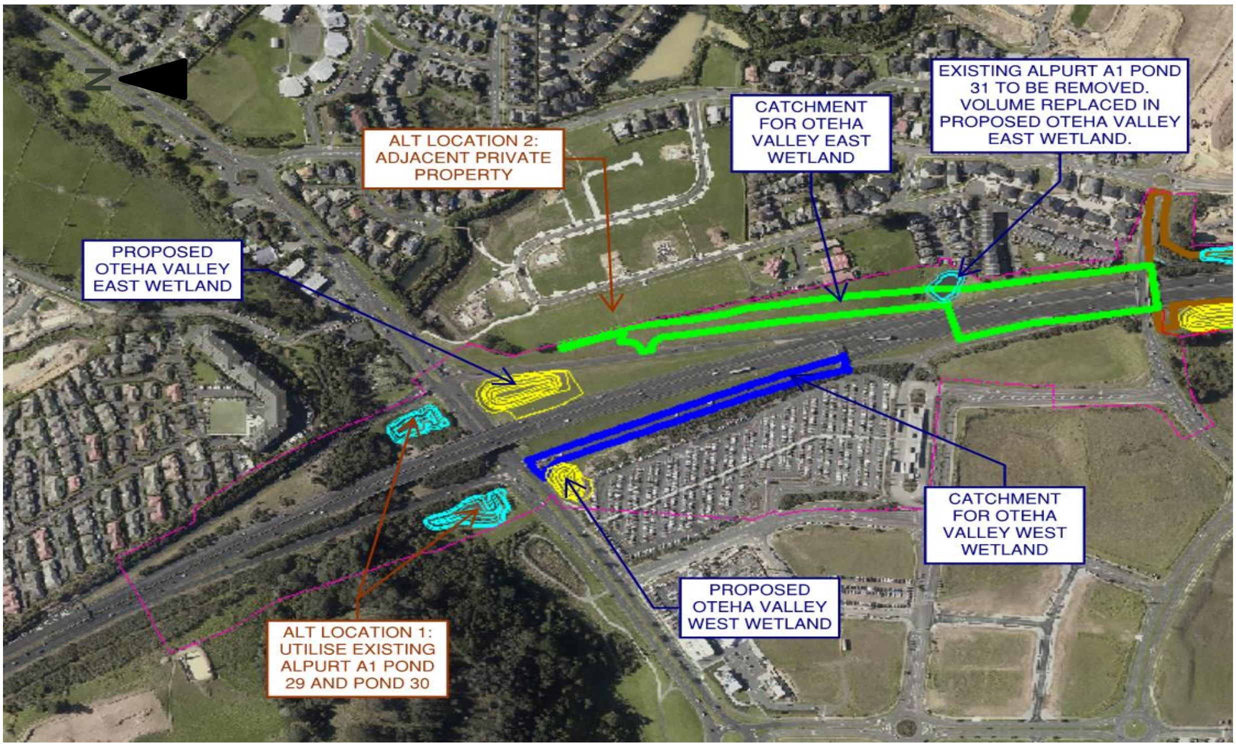
The attenuation requirements have been determined by comparing the post-development peak flows with the pre-development peak flows using the AC stormwater flood model. The model shows that no buildings downstream were inundated in the 100-year ARI event. However, properties downstream are flooded in the 10-year ARI event. Therefore attenuation of peaks flows has been provided for the 2-year and 10-year ARI event in accordance with E8.6.1(3)(a) in the AUP.

The preferred option for this sub-catchment is to provide:

- Two new water quality and quantity wetlands adjacent to the Oteha Valley Road on and off-ramps:
  - Oteha Valley East Wetland; and
  - Oteha Valley West Wetland.

The wetland locations and the catchments they serve are illustrated in **Figure 22**. The proposed wetlands are located at the bottom of the motorway catchment and close to the outlet at Lucas Creek.

Figure 22 BPO and alternatives for OV2M sub-catchment



The wetlands will discharge to Lucas Creek via a new outfall with appropriate erosion protection. The additional discharge volume to Lucas Creek as a result of the Project will be approximately 740m^3 in the 100-year ARI event.

This option is the preferred design for this sub-catchment for the following reasons:

- Wetland devices provide quantity and quality functions, provide excellent filtration of contaminants and have low maintenance costs;
- An above ground device is preferred for safe long term maintenance and operation;
- Safe access is available to the wetlands from local road on Oteha Valley Road for maintenance;
- This location is ideal for hydraulics as it is close to low point and outlet stream;
- No additional land acquisition is required;
- The SEA at Lucas Creek is avoided; and
- No retaining walls are required.

8.5.2 McClymonts to Spencer (M2S) Catchment

The proposed stormwater management for this sub-catchment is summarised in **Table 26**.

Table 26 M2S Stormwater Management Proposed

Stormwater Management	Yes/No
Water quality	Yes – 75% TSS removal (100% of total HUR to be treated)
Detention	Yes – SMAF1
Retention	No
Peak Flow Attenuation	Yes – Q_2, Q_{10}, Q_{100}

Stormwater runoff from the wetland is proposed to discharge to (CU-EX-03) via an existing outfall with new erosion protection (OF5). Stormwater will enter AC pipe network on Don McKinnon Drive, before discharging to Albany Lake Reserve, adjacent to Civic Crescent. The additional discharge volume will be approximately 410m^3 in the 100-year ARI event.

In determining the attenuation requirements for this catchment, a precautionary approach was taken to provide attenuation for events up to the 100-year ARI event within the McClymonts Pond instead of discharging directly to Albany Lakes Reserve as it has been suggested in discussions with AC that the Albany Lakes within the Reserve are near capacity.

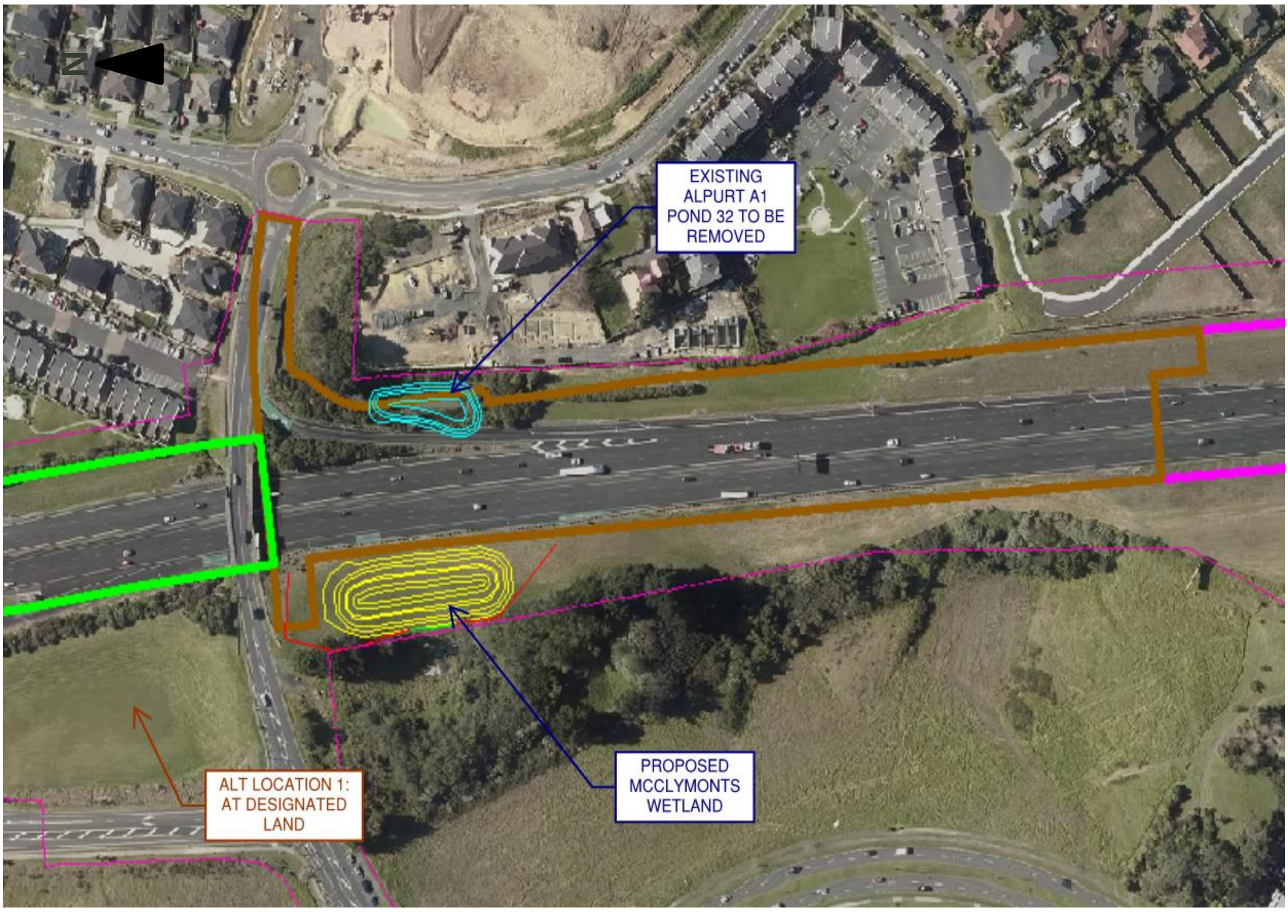
The Albany Lakes – Stormwater Operation & Maintenance Manual (2007) has been reviewed to understand the function of the existing pond in Albany Lake Reserve. It was found that the existing State Highway catchment is already included in the design of the ponds. Although the catchment was included, there is no information available regarding the percentage of imperviousness assumed for pond design. Without thorough understanding of flood risks caused by the overtopping of the Albany Lakes, it is proposed that a conservative approach is adopted and attenuation is provided for the 100-year ARI event for the McClymonts to Spencer sub-catchment.

The preferred alternative for this sub-catchment is to provide:

- One new water quality and quantity control wetland (McClymonts Wetland), located opposite the existing Alpurt A1 Pond 32 to be removed on the other side of SH1.

The wetland location and the catchment it serves is illustrated in **Figure 23**.

Figure 23 BPO and alternatives for M2S sub-catchment



This is considered the BPO for this sub-catchment for the following reasons:

- Wetland devices provide quantity and quality functions, provide excellent filtration of contaminants and have low maintenance costs;
- An above ground device is preferred for safe long term maintenance and operation;
- The location is ideal for hydraulics as it is close to outlet point; and
- No additional land acquisition is required.

8.5.3 Spencer to Rosedale (S2R) Catchment

The proposed stormwater management for this sub-catchment is summarised in Table 27.

Table 27 S2R Stormwater Management Proposed

Stormwater Management	Yes/No
Water quality	Yes – 75% TSS removal (100% of total HUR to be treated)
Detention	Yes – SMAF2
Retention	No
Peak Flow Attenuation	Yes – Q_2, Q_{10}, Q_{100}

The attenuation requirements have been determined by comparing the post-development peak flows with the pre-development peak flows using the AC stormwater flood model. The model indicates potential of increased flood levels downstream in the 100-year ARI event. Therefore attenuation of peaks flows has been provided for the 2-year, 10-year and 100-year ARI are in accordance E8.6.1(3)(a) in the AUP.

This sub-catchment discharges to Oteha Stream through a number of outfall structures. There are two existing Alpurt ponds (Pond 34 and Pond 35) near the motorway low point in the sub-catchment. Due to existing development in this area, there is limited open space available for locating wetlands near the low points in this sub-catchment. As such, the options assessment involved looking at a variety of devices to manage stormwater runoff in the sub-catchment.

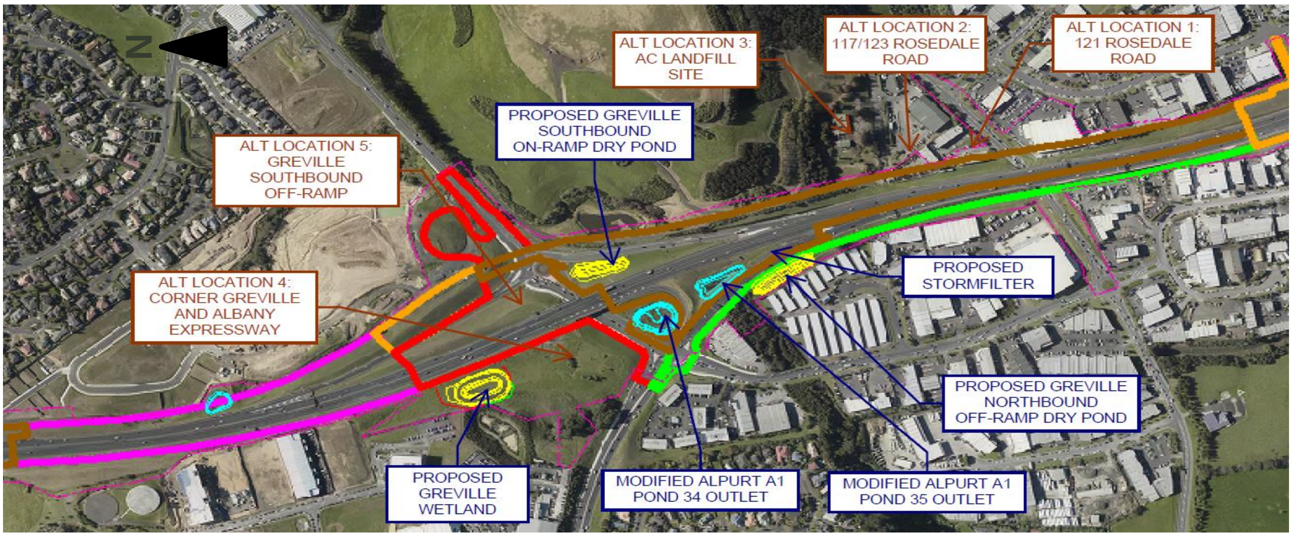
The preferred option for this sub-catchment is to provide:

- A new water quality and quantity control wetland:
  - Proposed Greville Wetland
- Modifications to two existing water quality and quantity control wetlands to increase live storage:
  - Alpurt A1 Pond 34
  - Alpurt A1 Pond 35
- A new water quality proprietary device:
  - Proprietary Device SF-S2R-1
- Two new water quantity control attenuation ponds:
  - Proposed Greville Southbound On-Ramp Dry Pond
  - Proposed Greville Northbound Off-Ramp Dry Pond

The wetland locations and the catchments they serve are illustrated in **Figure 24**.

The Greville Wetland provides quality and quantity management and replaces the existing Alpurt A1 Pond 33. The outlets of existing Alpurt A1 Pond 34 and 35 will be modified to provide additional live volume for attenuation of peaks flows. This additional volume is required to provide adequate peak flow attenuation for the sub-catchment to pre-development flow rates. The two dry ponds have been proposed to minimise the area discharging to Alpurt Pond 35, which is already undersized for the catchment discharging to it. Although wetlands are preferred over dry ponds due to the ability to provide treatment, wetlands cannot be provided due to the narrow space constraint. Existing Alpurt Pond 35 has been found to be undersized through topographic survey. An additional proprietary device has been proposed to provide primary treatment before stormwater enters Alpurt Pond 35 for flow control. Due to the hydraulic head requirements of a proprietary device, the permanent water depth in Alpurt Pond 35 may need to be reduced.

Figure 24 BPO and alternatives for S2R sub-catchment



This is considered the preferred option for this sub-catchment for the following reasons:

- It will provide treatment of all new and existing HUR pavement areas;
- It will provides adequate stormwater quantity management performance;
- It utilises existing stormwater management devices to minimise the number of new assets required; and
- No additional land acquisition is required.

8.5.4 Rosedale to Constellation (R2C) Catchment

The proposed stormwater management for this sub-catchment is summarised in **Table 28**.

Table 28 R2C Stormwater Management Proposed

Stormwater Management	Yes/No
Water quality	Yes – 75% TSS removal (100% total HUR to be treated)
Detention	Yes – SMAF2
Retention	No
Peak Flow Attenuation	Yes – Q_2, Q_{10}, Q_{100}

The above attenuation requirements have been determined from an analysis of the capacity of the downstream pipe system. It was found by reviewing AC's stormwater model that the downstream 1200mm diameter culvert is under capacity and acts as a restriction for the upstream catchment. To avoid impacting flood levels upstream, and overflow volumes into Watercare ponds, attenuation of peak flows up to the 100-year ARI event has been proposed for this sub-catchment.

The preferred option for this sub-catchment is to provide:

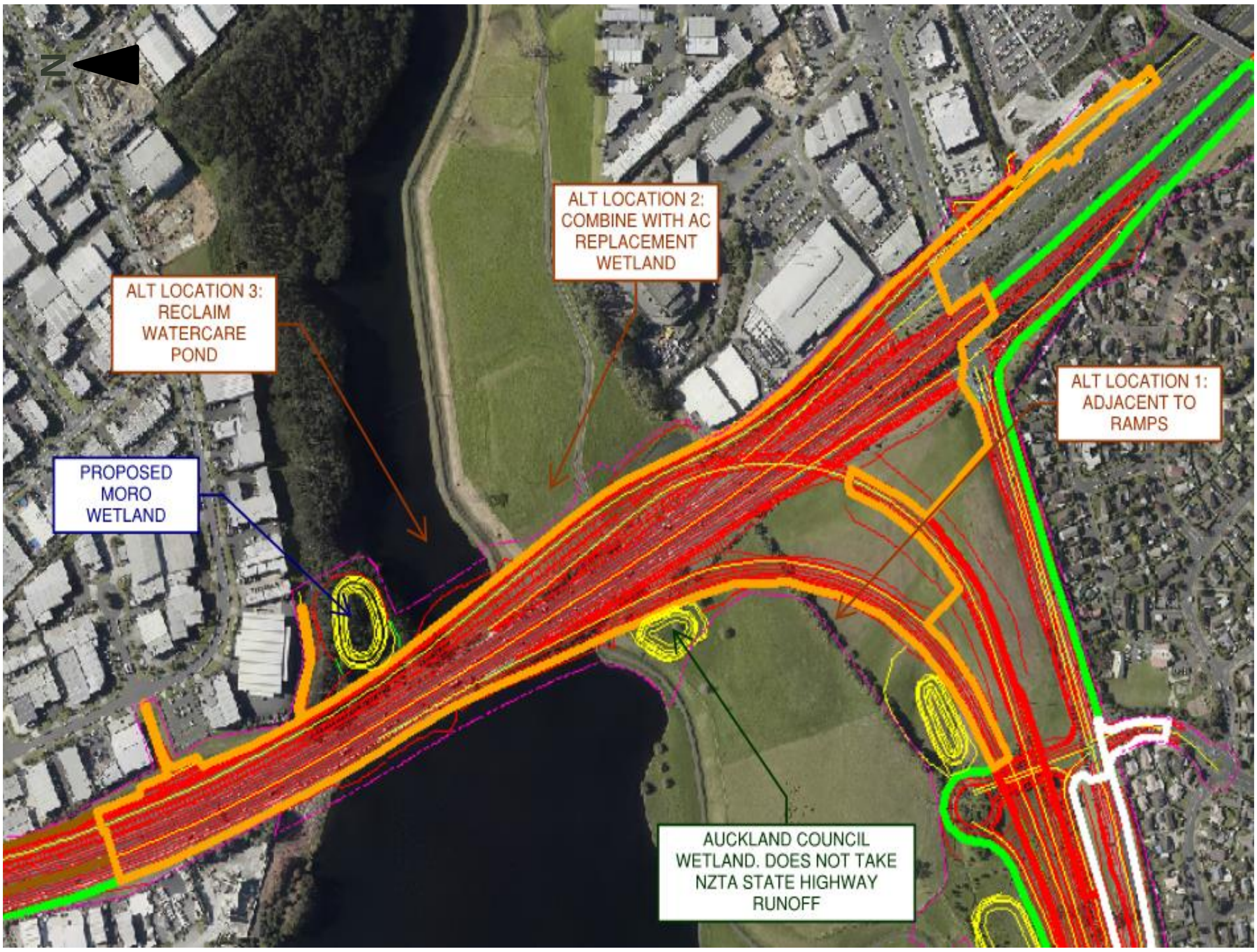
- A water quality and quantity control wetland at the location of the existing AC Moro Pond, adjacent north of Watercare Pond 2.

The wetland location and the catchment it serves is illustrated in **Figure 25**. The proposed wetland is located ideally at the bottom of the motorway catchment and close to the outlet (existing 1200mm diameter culvert under SH1), allowing it to serve approximately 8.5ha of impervious area.

The existing Moro Pond provides a small live volume for attenuation of external catchments (approx. 50m^3). The volume within Moro Pond is replaced as part of the AC Ponds replacement BPO. The proposed Moro Wetland has been sized to allow for stormwater runoff from:

- The existing and new HUR within this catchment; and
- The Constellation Bus Station extension, located adjacent catchment boundaries as shown in **Figure 25**.
- Due to the ideal hydraulic conditions, and lack of other open space options for stormwater management near the motorway low point, this is considered the BPO for this sub-catchment.

Figure 25 BPO and alternatives for R2C sub-catchment



This is considered the preferred option for this sub-catchment for the following reasons:

- It provides both adequate water quality and quantity management;
- Wetland devices provide quantity and quality functions, provide excellent filtration of contaminants and have low maintenance costs;
- It involves the use of an above ground device which will result in safe long term maintenance and operation;
- It is ideal in terms of hydraulics as it is close to low point and outlet stream;
- There are no other above-ground alternatives near the motorway low-point; and
- New wetland in location of existing pond.

8.5.5 Constellation to Paul Matthews (C2PM) Catchment

The proposed stormwater management for this sub-catchment is summarised in **Table 29**.

Table 29 C2PM Stormwater Management Proposed

Stormwater Management	Yes/No
Water quality	Yes – 75% TSS removal (89% total HUR to be treated)
Detention	Yes – SMAF2
Retention	No
Peak Flow Attenuation	Yes – Q_2, Q_{10}, Q_{100}

The above attenuation requirements have been determined from an analysis of the downstream network. It was found by reviewing AC's stormwater model that the downstream artificial watercourse adjacent to Watercare Pond 1 overflows into Pond 1 during extreme rainfalls. To avoid increasing overflow volumes into Watercare ponds, attenuation of peak flows up to the 100-year ARI event has been proposed for this sub-catchment.

The preferred option for this sub-catchment is to provide:

- A water quality and quantity control wetland (Caribbean Wetland) to the east of the proposed SH18 Caribbean Drive off-ramp roundabout.

The wetland location and the catchment it serves is illustrated in **Figure 26**. The proposed wetland is located in an ideal location at the bottom of the motorway catchment, allowing it to serve a large area of impervious area. The location of the new wetland also allows it to serve the existing SH1/UHH northbound off-ramp, which enables the removal of the existing StormFilter without impacting on treatment performance.

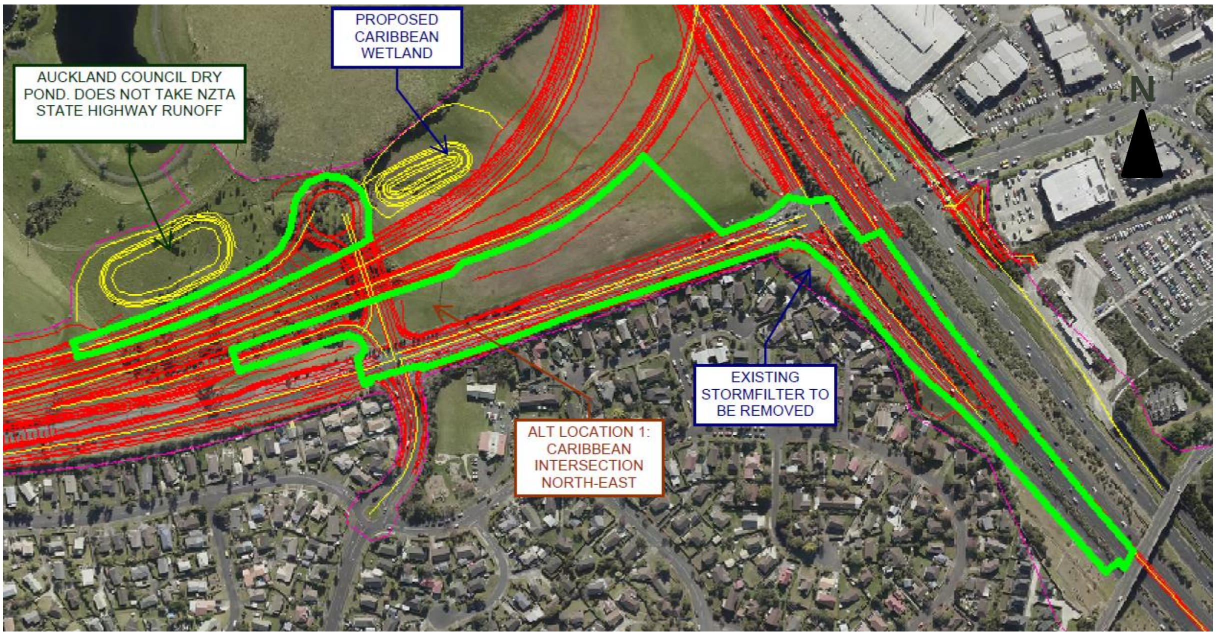
The section of UHH between the Caribbean Drive intersection and existing Paul Matthews Road intersection proposed to be designated as a local road, hence the design of the Caribbean Wetland catchment excludes this area. This area is proposed to be treated by a swale and discharge to the proposed upsized culvert. Refer to the Stormwater Layout Plans in **Appendix A** for details.

8.5.5.1 Reclamation of existing drainage channels

There are a number of existing concrete-lined channels within this sub-catchment as described in **Section 2.4.4**. Some of these channels are proposed to be reclaimed as shown in the Stormwater Layout Drawings in **Appendix A.**

The reclamation is required due to the proposed alignment of the proposed SH1 to SH18 connections. Options to culvert the existing concrete channels along their existing alignments have been considered. However these options were not considered to be practicable due to safety, construction and operation risks associated with the construction of a major culvert (1350mm Ø) at a significant depth (13m) under a large embankment.

Figure 26 BPO and alternatives for C2PM sub-catchment



This is considered the preferred option for this sub-catchment for the following reasons:

- It provides both good water quality and quantity management;
- Wetland devices provide quantity and quality functions, provide excellent filtration of contaminants and have low maintenance costs;
- It involves the use of an above ground device which will result in safe long term maintenance and operation; and
- It is ideal in terms of hydraulics as it is close to low point and outlet stream.

8.5.6 Paul Matthews to Albany Highway (PM2AH) Catchment

The proposed stormwater management for this sub-catchment is summarised in **Table 30**.

Table 30 PM2AH Stormwater Management Proposed

Stormwater Management	Yes/No
Water quality	Yes – 75% TSS removal (100% of total HUR to be treated)
Detention	Yes – SMAF2
Retention	No
Peak Flow Attenuation	Yes – Q_2, Q_{10}

The attenuation requirements have been determined by comparing the post-development peak flows with the pre-development peak flows (MPD scenario) using the AC stormwater flood model. The model shows that whilst no buildings downstream are inundated in the 100-year ARI event, there are a number of properties downstream that are flooded in the 10-year ARI event. Therefore attenuation of peaks flows has been provided for the 2-year and 10-year ARI event in accordance with Rule E8.6.1(3)(a) of the AUP.

The location identified for the wetland during the preliminary design phase was a grassed location adjacent to the UHH within Rook Reserve, to the north of Rook Place. Two alternative sites were identified, both within the Bluebird Reserve: one site within the grassed open area north of the children's playground, and another in an area of bush within the same reserve.

All options would require the use of a proprietary device to filter the stormwater prior to discharge into the local streams. In all other aspects, the Bluebird Reserve options would provide a comparably suitable area to the Rook Reserve option for a stormwater management wetland that would also provide an amenity feature, accessible by the public.

An MCA process was undertaken in conjunction with AC Parks on all three sites (as described in Section 7 of the AEE in **Volume 2**), with the Rook Reserve site being selected as the preferred location. Refer to **Appendix P2** for further information.

The alternative design drawings for Bluebird Reserve and a full assessment of its water quality and quantity performance is included within **Appendix R**. Both the Roook and Bluebird options have been included within the proposed designation because the Local Board (which administers both reserves) is still in the process of determining its preferred option. Once the position of the Local Board is finalised, the designation line can be drawn back from the discarded option.

From a stormwater management perspective, the preferred option for this sub-catchment is to provide:

- A water quality and quantity control wetland located adjacent to the Alexandra Stream within Rook Reserve; and
- A proprietary cartridge device (StormFilter or similar approved) is proposed at the abandoned Z Service Station ramp to improve treatment performance for this sub-catchment by treating a significant amount of existing impervious area.

A wetland within Rook Reserve would ideally be located near the low point of the State Highway, thus maximising the catchment area (and new impervious area) that the wetland is able to serve. The low point for this sub-catchment is located on the west side of Alexandra Stream. It is not hydraulically possible to convey flows from the low point back to the wetland in Rook Reserve on the east side of Alexandra Stream. As such, the Rook Wetland would serve the sub-catchment east of Alexandra Stream, where most of the new impervious areas in the sub-catchment are to be constructed. The existing impervious areas west of the proposed wetland, which contains little new impervious area resulting from the Project, is proposed to be treated using a proposed proprietary device.

Figure 27 BPO and alternatives for PM2AH sub-catchment

This is considered the preferred option for this sub-catchment for the following reasons:

- It achieves the best practicable water quality and quantity outcomes for the Project when compared with alternatives;
- A proprietary device is proposed to treat a significant amount of existing impervious areas in this sub-catchment to improve the treatment performance of this option;
- The Rook Wetland can be safely accessed from Rook Place;
- The Rook Wetland is located in undeveloped open space within the existing Reserve, and is away from residents and businesses; and
- The Rook Wetland is located near the low point in the State Highway and adjacent to the Alexandra Stream (ultimate discharge point for the sub-catchment).

8.6 Auckland Council Ponds

There are three existing AC stormwater ponds that are to be removed as a result of the Project footprint. These are, the Constellation Pond, ARC Refuse Pond and Moro Pond (refer to the Stormwater Layout Plans in **Appendix A** for pond locations). The proposed motorway, ramps and busway are constructed directly on top of the existing ponds. The following sections describe the existing stormwater system performance, the key stakeholder issues, the mitigation options considered and the proposed option.

8.6.1 Existing Environment

8.6.1.1 Overview

Under existing conditions, the Constellation Pond attenuates stormwater runoff from the Unsworth Heights residential catchment. The pond discharges to an existing artificial watercourse adjacent to Pond 1, which then passes under SH1 and connects to a bell-mouth structure located at the south western corner of Pond 2.

The ARC Refuse Pond treats and attenuates flows from the upstream AC catchment east of SH1. The discharge from the ARC Refuse Pond flows west under SH1 to join the Pond 1 artificial watercourse, before flowing back under SH1 to connect to the bell-mouth structure.

The bell-mouth structure also receives runoff from the Pond 2 artificial watercourse, then discharges through a 1200 mm diameter pipe under Pond 2 to the existing Moro Pond, where only minor attenuation is provided. Flows from Moro Pond enter a drop headwall structure under SH1 (1200mm diameter pipe), and discharge to a modified watercourse to the north of Pond 1 (at OF12). Some additional local flows enter the system at Moro Pond from the small catchment north of Pond 2.

8.6.1.2 Existing System Performance

The existing system performance is based on the results of the AC MIKE FLOOD model (refer to **Section 3.2.1** details of the AC flood models). **Figure 28** provides a visual overview of the stormwater system in the vicinity of the AC ponds which are to be removed, with key information such as flow rates, volumes and levels at key locations for the 100 year ARI storm event (climate change to 2121) under existing development conditions. Review of the results indicates:

- Discharges from this stormwater sub-system are limited to approximately 4.7m^3/s by the 1200mm diameter pipe which runs under Pond 2;
- There are significant stormwater overflows into both Watercare Pond 1 and Watercare Pond 2 from the artificial watercourses at the southern pond extents;
- The peak flow at the Constellation Pond outlet is approximately double that of the ARC Refuse Pond; and
- Moro Pond is providing minor attenuation (50m^3) in comparison to the Constellation Pond and ARC Refuse Pond.

Figure 28 Summary of existing stormwater system

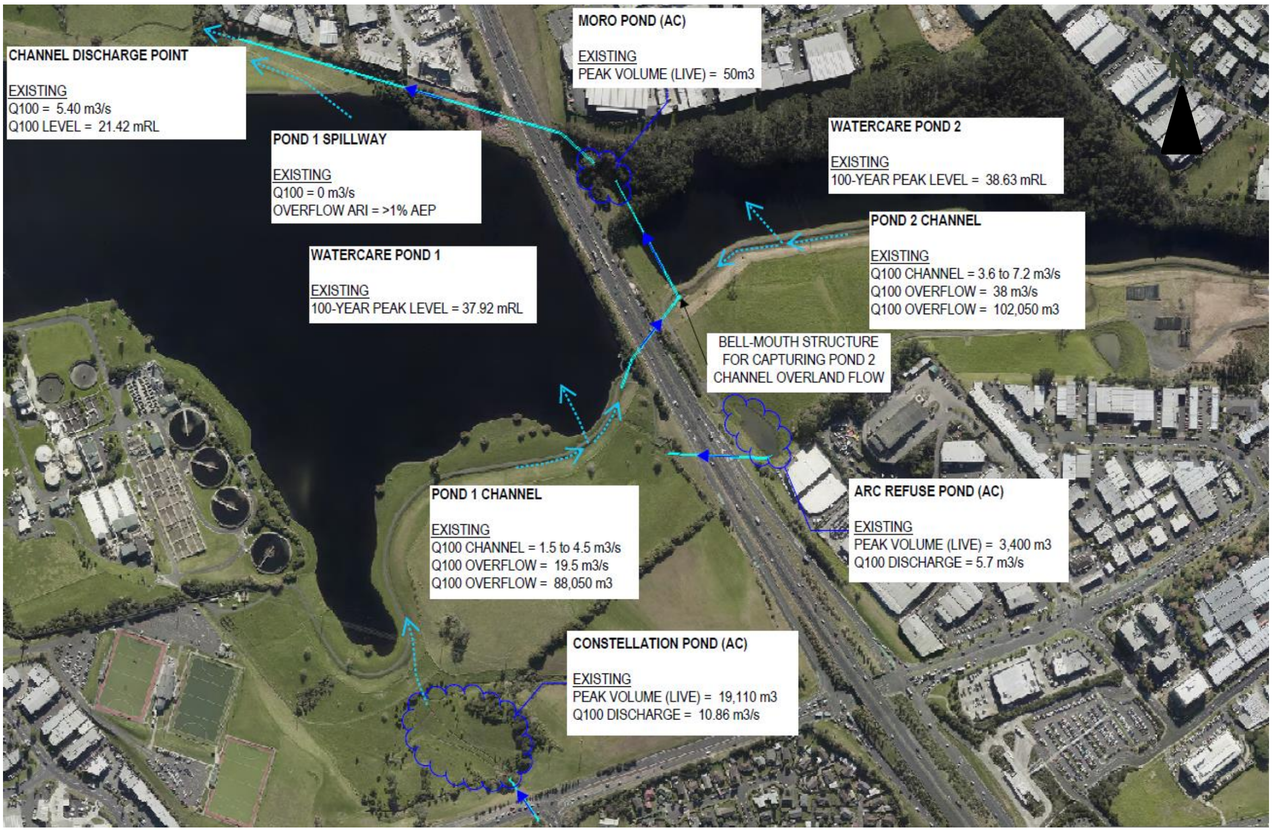


Table 31 summarises the key attributes for the existing ponds, sourced from the AC flood model and the Stormwater Ponds Upgrade Rosedale Wastewater Treatment Plant Area report (SKM, November 2012) provided by AC.

Table 31 Existing Auckland Council Ponds Summary (100 year ARI storm event, with climate change to 2121 – Existing Development conditions)

Pond	Permanent Water Volume (m^3)	Live Volume (m^3)	Pond Base Level (mRL)	Permanent Water Level (mRL)	Peak Water Level (mRL)	Live Volume Depth (m)
Moro Pond	0	50	N/A	Dry Pond	N/A	N/A
ARC Refuse Pond	1,600	3,400	Unknown	39.1	41.65	2.55
Constellation Pond	0	19,100	38.1	Dry Pond	41.4	3.3

8.6.2 Stakeholder Consultation

Due to the location of the existing AC ponds, the proposed options have the potential to affect NZ Transport Agency, AC and Watercare assets. **Table 32** sets out the key considerations and concerns identified in discussions with these stakeholders.

Table 32 Stakeholder Concerns Summary – Removal of AC Ponds

Stakeholder	Issue / Concerns	Mitigation
The NZ Transport Agency	Flood protection of State Highway 1 and State Highway 18	Culvert under State Highway 18 is proposed to be upsized
AC	Flooding further downstream in the Oteha Valley Catchment - as identified in Oteha Valley Catchment model (AC, 2013) Tailwater effects for Unsworth Heights reticulation system upstream of the existing Constellation Pond	Proposed replacement system provides similar flooding performance achieved by existing system, both upstream and downstream
Watercare	Interference of proposed ponds with future expansions Increased stormwater overflow affecting future wastewater treatment performance Capacity of Pond 1 to Pond 2 link Activation of Pond 1 spillway	The proposed system minimises areas required by replacement devices The proposed system aims to replicate volume and frequency of overflows to Watercare Ponds (as a whole) The proposed system reduces stormwater overflow into Pond 1, where the wastewater treatment process is undertaken (but increases overflow into Pond 2)

8.6.3 Options Assessment

8.6.3.1 Overview

The aim of the replacement stormwater system is to replicate the function, performance and level of service of the existing stormwater system, whilst addressing stakeholder concerns identified in **Table 32**. This has been achieved by:

- Maintaining or lowering pre-development overflow volumes into Watercare ponds (as a whole), and the frequency of these overflows;

- Maintaining or lowering pre-development flow rates and peak water levels at the outlet of the system (in the modified watercourse north of Pond 1). This is to ensure flood levels downstream are not worsened; and
- Maintaining or lowering pre-development peak water levels upstream of the existing Constellation Pond (an identified flooding location).

A number of options were considered for the replacement stormwater system, which were developed in conjunction with Watercare and AC. A summary of the options is provided in **Table 33**. Further detail on each option is provided in **Appendix Q**.

Table 33 Summary of options considered

Option	Constellation Pond	Ex Culvert East to West under State Highway 1	Ex Culvert West to East under State Highway 1	ARC Refuse Pond
Option 0 *Do nothing*	Remove without replacement	Retain	Retain	Remove without replacement
Option 0A *High-Level Dry Pond*	High-Level Dry Pond	Retain	Retain	Remove without replacement
Option 1 *Ramps wetland*	Remove without replacement	Abandon	Retain	Remove without replacement
Option 2 *Wetland over reclaimed Pond 2*	Remove without replacement	Abandon	Retain	Reclaim on top of Pond 2 (30,000m^3)
Option 2a *Wetland over reclaimed Pond 2, with retained culvert*	Remove without replacement	Retain	Retain	Reclaim on top of Pond 2 (30,000m^3)
Option 3 *Wetland over reclaimed Pond 1*	Reclaim on top of Pond 1 (30,000m^3)	Retain	Retain	Remove without replacement
Option 4a *2x wetlands on-land*	Replace adjacent to off-ramp (15,800m^3)	Abandon	Retain	Replace east of State Highway 1 (15,400m^3)
Option 4b *2x wetlands with one reclaimed over Pond 2*	Replace adjacent to off-ramp (15,800m^3)	Abandon	Retain	Reclaim on top of Pond 2 (15,000m^3)
Option 5 *Wetland reclaimed over Pond 1 with upgrade to* artificial *watercourse*	Replace adjacent to off-ramp (15,800m^3)	Retain	Retain	Remove without replacement

Details of the do nothing (no mitigation) and high-level dry pond option (proposed) are provided below. A full analysis of the remaining options is provided in **Appendix Q**.

8.6.3.2 Option 0 - Do Nothing

The 'do nothing' option involves abandoning both existing ARC Refuse Pond and Constellation Pond with no replacement, as shown in **Figure 29**. The purpose of this option is to understand the hydraulic effects of not providing any mitigation works.

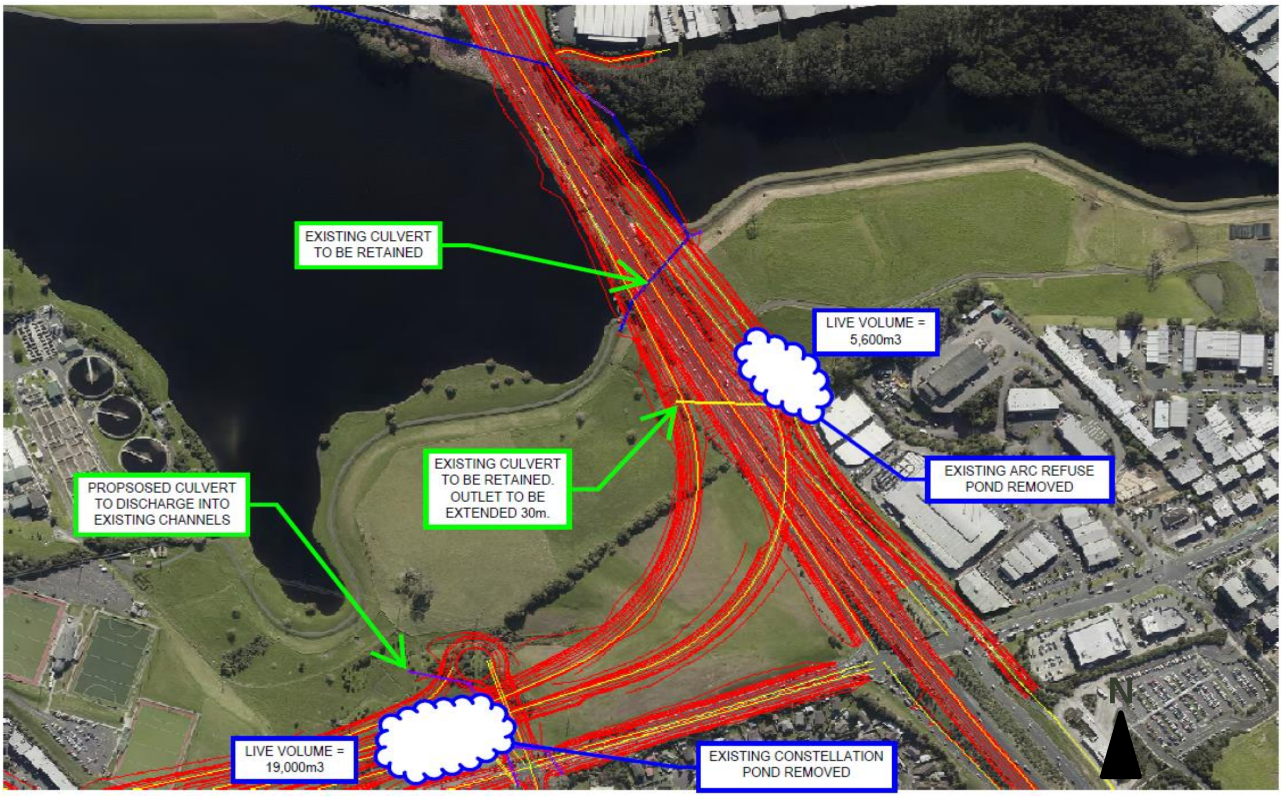
This option represents the lowest cost of the options assessed. Review of the results indicates that this option actually has much less impact on overflows to Watercare ponds that expected. Further analysis of the results indicates that this is due to timing effects of the hydrograph peaks from the Unsworth Heights residential catchment to the west of SH1 and the commercial catchment to the east of SH1. It appears that in the existing case, the ARC Refuse Pond attenuation actually has the effect of delaying the peak from this catchment and therefore causing the peaks from the two catchments to coincide. Removing the ponds, thus allowing both catchments to drain freely removed the coincidental peak flows from both catchments in the existing scenario, therefore reducing peak levels and overflows in the ponds.

Review of the modelling results indicates the following:

- For the 100 year ARI event:
  - Total overflow volumes into the ponds were increased by 3%; and
  - The peak water levels upstream of ARC Refuse Pond were increased by 70mm;
- For the 10 year ARI event:
  - Total overflow volumes into the ponds were increased by 7%.

Due to the increase in flows into the Watercare ponds, another option was generated (Option 0A) with a 'high-level' dry pond which provides additional storage capacity at a higher level (without affecting the lower flows) to reduce inflow volumes into the Watercare ponds.

Figure 29 Option 0 'Do Nothing' Schematic



Option outcomes:

- Cost: Option with minimum cost;
- Hydro: Small increases in overflows into Watercare ponds; and
- Treatment: Reduced treatment from existing scenario.

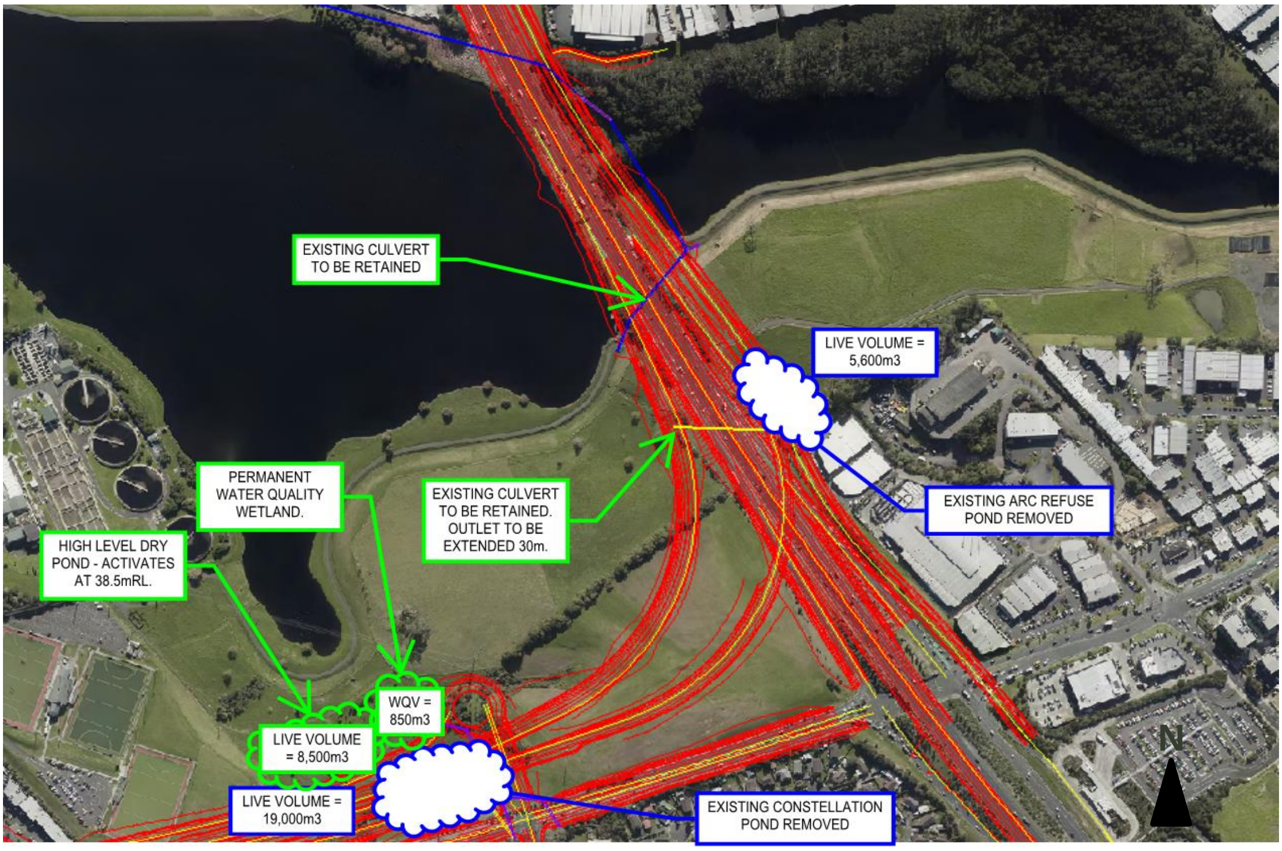
8.6.3.3 Option 0A – High-level Dry Pond

This option has been developed from the do nothing option (Option 0) to further reduce overflows into Watercare ponds. A schematic of the layout is shown in **Figure 30**. A high-level dry pond is proposed to reduce overflows into the Watercare ponds. Review of the hydraulic grade line upstream of the bell mouth indicated that the water level was ponded in the artificial watercourses, and therefore this pond could be situated at any location along the artificial watercourses, assuming it is above the required level and not reducing flood storage as a result of earthworks. The most suitable place for the placement of this pond was determined to be adjacent to the UHH off-ramp from SH18, due to minimal land requirements.

The dry pond's inlet weir is set at a level such that it only activates in high flows. In the beginning of the storm, runoff can drain freely without attenuation. Once the water level builds up to the weir level (via the tailwater conditions), stormwater overflows into the dry pond instead of the Watercare ponds. This arrangement allows the size of the dry pond to be minimised.

However, a dry pond arrangement does not provide treatment of stormwater. Therefore, a permanent water quality wet pond has been proposed on the west side of SH1 to replacement the treatment function of the existing ARC Refuse Pond.

Figure 30 Option 0A 'High-Level Dry Pond' schematic



Option outcomes:

- Cost: Minimal land acquisition required;
- Hydro: Reduced overflows to Watercare Ponds; and
- Treatment: Reduced treatment from existing scenario.

8.6.3.4 Results of Options Assessment

The design has considered several options to reconfigure the existing ponds to manage the wider external stormwater runoff peak flows to pre-development levels. The key factors that influenced the selection of the preferred option included a combination of:

- Construction cost;
- Land acquisition cost;
- Construction risk and Safety in Design considerations;
- Stakeholder (AC and Watercare) preferences; and
- Hydraulic performance (maintain pre-development performance).

Table 34 summarises the outcomes of the options assessment.

Table 34 Option Assessment Summary – Comparison of Key Factors

Option	Hydraulic Performance Satisfactory (Y/N)	Stakeholder Considerations	Safety in Design Considerations	Overall Rank
Option 0 – Do nothing	Y	Preferred by Watercare due to minimal land requirements.	Preferred. No retaining walls, deep cuttings or reclamation.	2
Option 0A – High-Level Pond	Y	Preferred by Watercare, due to minimal land required and overflow reduced.	Preferred. No retaining walls, deep cuttings or reclamation.	1
Option 1	Not assessed	Option raised by the NZ Transport Agency to contain all works are within Designation	Risks associated with high retaining walls construction and groundwater inundation.	8
Option 2	N	Preferred by Watercare, as it keeps land south of Pond 2 vacant.	Risks associated with reclamation.	4
Option 2a	N	Similar to Option 2a, but with an additional asset for the NZ Transport Agency (culvert).	Risks associated with reclamation	5
Option 3	Y	Watercare prefers to reclaim Pond 2 rather than Pond 1.	Risks associated with reclamation.	3
Option 4a	N	Watercare is against location of pond south of Pond 2.	Preferred. No retaining walls, deep cuttings or reclamation.	7
Option 4b	N	Preferred by Watercare, due to minimal land required.	Risks associated with reclamation.	6
Option 5	Not assessed	Preferred by Watercare, due to minimal land required.	Preferred. No retaining walls, deep cuttings or reclamation.	8

8.6.4 Preferred Option

Based on a comparison of effects at critical locations, the preferred option is Option 0A. This involves constructing a dry pond adjacent to the UHH off-ramp from SH18. Runoff enters the pond via a high-level weir so that the pond acts as a backwater storage pond for events greater than a 10 year ARI event. The pond is drained with a culvert which discharges to the Pond 1 cut-off drain.

To replace the existing treatment function of the ARC Refuse Pond, a replacement wet pond with a permanent water depth of 2m is proposed to replace the existing WQV volume like-for-like. The existing ARC Refuse Pond is short-circuited (pond inlet and outlet are adjacent to each other), which significantly reduces treatment performance. The proposed replacement pond addresses this issue and would result in improved treatment performance over the existing pond.

The proposed Moro Wetland provides an adequate volume to replace the existing detention functions of the existing ARC Refuse Pond and Constellation Pond. During the detention design event, flood modelling has confirmed that the post-development peak flow and velocity at the discharge location (at the modified watercourse downstream of OF12) are less than pre-development. As such, the post-development impact on stream erosion are considered to be no worse than pre-development during the detention design event. Refer to **Section 7.2** for further details.

Table 35 summarises key characteristics of the replacement devices.

Table 35 Proposed Replacement of Auckland Council Ponds – Summary

Pond	Permanent Water Volume (m3)	Live Volume (m3)	Pond Base Level (mRL)	Permanent Water Level (mRL)	Peak Water Level (mRL)	Live Volume Depth (m)
ARC Refuse Wet Pond	1,800m3	N/A	36.5mRL	38.5mRL	38.8mRL	N/A
High-level dry pond	N/A	8,500m^3	37.2mRL	N/A	39.4mRL	2.2m

9 Summary and Conclusions

9.1 Proposed Stormwater Management

The proposed stormwater management system for the Project addresses both quality and quantity and has been selected using a BPO approach. The proposed devices include a combination of planted swales and wetlands, dry ponds, wet ponds and AC approved proprietary treatment devices.

9.2 Stormwater Quantity Management Summary

The Project results in an overall increase in the volume of stormwater runoff generated during rainfall events in the Oteha and Lucas Creek catchments due to the increase in impervious area. Unmitigated, the increase in runoff volume has the potential to increase downstream peak discharges during flood events, causing stream erosion and increased flood water levels.

Peak flow attenuation is provided for discharge to Oteha Stream (100 year ARI event) and to Alexandra Stream and Lucas Creek (10 year ARI event). A comprehensive flood assessment has been carried out to determine the cumulative Project impacts on flows and peak water levels in the receiving catchment from multiple discharges in the catchment. The flood risk has been managed in the Project design as follows:

- The proposed devices include a combination of wetlands and dry ponds for flow control;
- Stormwater quantity control devices have been sized in accordance with the AUP and TP108; and
- Overland flow paths have been designed to convey stormwater within the designation footprint and immediately adjacent to the motorway to ensure the 100 year ARI flow is managed without the risk of blockage by the motorway structures, and to minimise flooding of neighbouring properties.

Overflows to Watercare Ponds have been assessed as part of the overall stormwater catchment modelling. The modelling shows that there will be a reduction in overflows into Watercare Pond 1, and no increase to the net overflow into the overall Watercare Pond system for the 2, 10 and 100 year ARI events.

The proposed stormwater quantity management will reduce flooding in most areas. In summary, the effects are as follows:

- Significant reduction (300mm to 460mm) in peak flood levels at Meadowood Reserve, identified by AC as a flood prone location with regards to flooding impacting on a nearby kindergarten;
- Up to 80mm increase in peak flood levels for the 100 year ARI event in Alexandra Stream downstream of UHH crossing. The increases do not extend beyond the Paul Matthews Road Bridge and that there are no buildings identified as at risk of above floor flooding (floor within 500mm of the 100 year ARI MPD flood level) in this location;
- Up to 70mm increase in peak flood level for the 100 year ARI event in Alexandra Stream immediately upstream of UHH crossing. The increase does not extend beyond the Barbados Drive Bridge and 500mm of freeboard for habitable floor levels will remain at the property at 125 Unsworth Drive; and
- There is a small increase (60mm in the 100 year ARI event) in peak water level within the shared underpass at the UHH/Alexandra Stream crossing. The increase in flooding does not impact the usability of the underpass, as it is already significantly under water in the current situation (2.4m depth of water in the 100 year ARI event within the underpass).

As a result of the stormwater management controls proposed for the Project, the assessment shows that predicted flood levels will decrease for a number of properties previously identified on flood maps and reporting as being at risk of flooding.

With regards to the Project's impacts on the hydrological regime, the only location where the hydrological regime is impacted to a noticeable degree is downstream of Moro Wetland discharges at the outlet to the modified channel. Rock armouring and lining to the channel bend will be installed as part of works separate to the Project in discussion with AC.

The stormwater quantity mitigation devices (including proposed flow attenuation devices, cutoff drains, culvert works, erosion protection at outfalls, etc.) will appropriately mitigate the potential surface water effects of the Project on the wider catchment.

9.3 Stormwater Quality Management Summary

During the operational phase, the effects of contaminants in stormwater from the Project on the downstream receiving environment will be mitigated by treatment devices designated in accordance with the AUP requirements, AC's TP10 and TR2013/035. A thorough BPO analysis has been undertaken to determine the best option for ensuring that any water quality effects are appropriately managed. There is approximately 8.3ha of additional impervious surface classified as HURs resulting from the Project.

The key stormwater quality management elements of the Project include:

- A treatment train approach to manage stormwater runoff from new and existing impervious areas across the Project has been provided, including dedicated at source catchpit devices and planted swales for capture and conveyance of stormwater runoff, and planted wetlands as the primary treatment means for treating stormwater runoff from the Project;
- Water quality treatment to 75% TSS removal on a long-term average basis is provided for approximately 99% of all HUR pavement areas within the Project area – which is a significant increase from the 52% treatment that is currently being provided for the existing HUR areas within the Project area; and
- Improved treatment performance is achieved through provision of water quality treatment of existing motorway areas that currently have no dedicated treatment facility.

Overall the proposed constructed wetlands, swales and proprietary devices are appropriate for managing the stormwater runoff from the Project. The effects of the Project on water quality are assessed in the Assessment of Surface Water Quality Effects.

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Aurecon New Zealand Ltd
Level 4, 139 Carlton Gore Rd
Newmarket Auckland 1023
PO Box 9762
Newmarket Auckland 1149
New Zealand

T +64 9 520 6019
F +64 9 524 7815
W aurecongroup.com