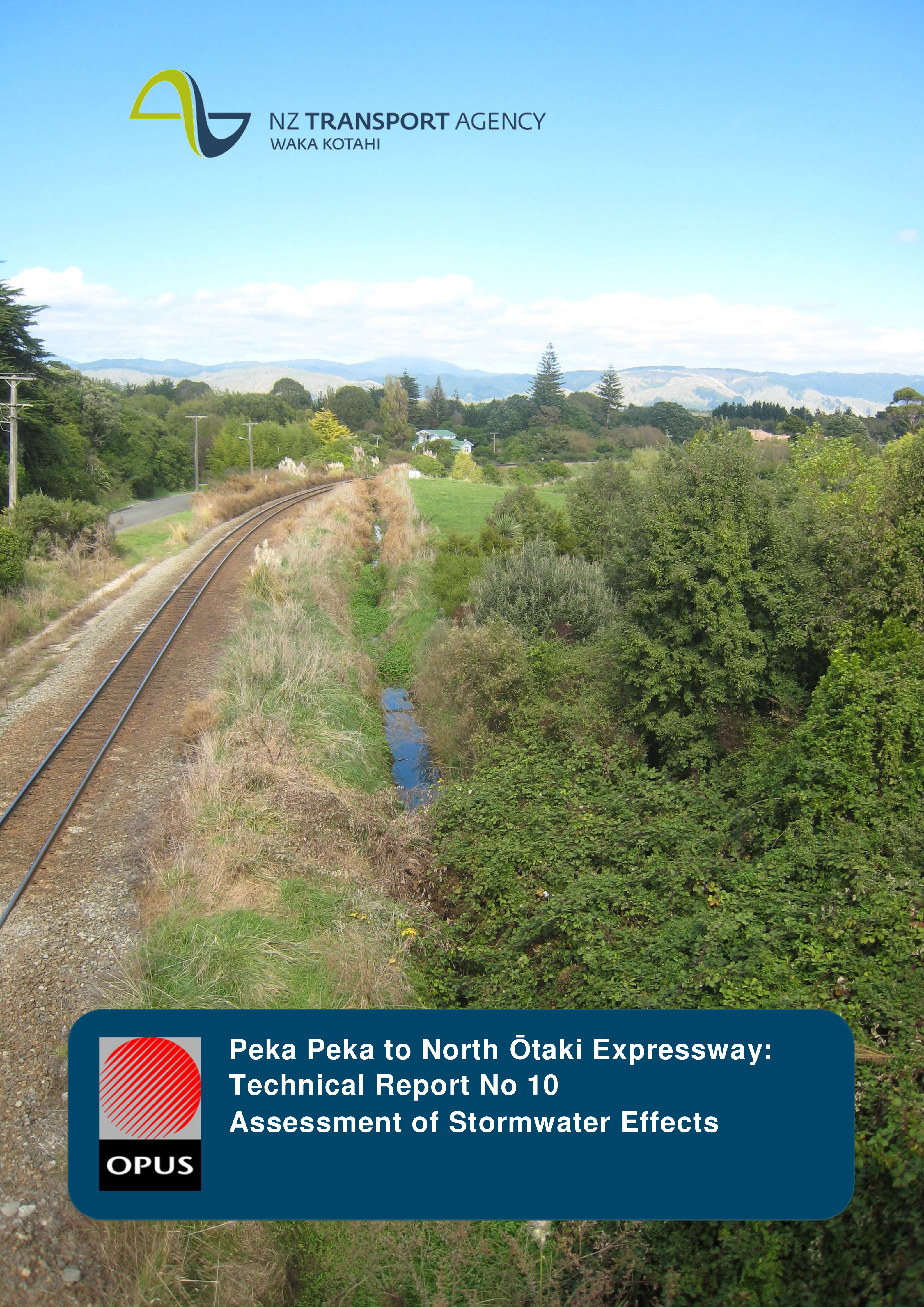

Peka Peka to North Ōtaki Expressway: Technical Report No 10 Assessment of Stormwater Effects

Peka Peka to North Ōtaki Expressway: Technical Report N^{o} 10 Assessment of Stormwater Effects

AEI: 2012/054

Prepared By
Richard Coles
Environmental Engineer

Prepared By
Warren Bird
Principal Environmental Engineer

Reviewed By
Glenn Jarvie
Senior Environmental Engineer

Approved for Release By
Mark Edwards
Project Design Manager

Opus International Consultants Ltd
Auckland Environmental Office
The Westhaven, 100 Beaumont Street
PO Box 5848, Auckland 1141
New Zealand

Telephone: +64 9 355 9500
Facsimile: +64 9 355 9584

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Contents

List of appendices

List of figures

List of tables

List of abbreviations

AEE	Assessment of effects on the environment
AEP	Annual Exceedance Probability[1]
ARC	Auckland Regional Council
BH	Bore hole
BPO	Best practicable option
CEMP	Contractor's Environmental Management Plan
DWVK	Deutscher Verband für Wasserwirtschaft und Kulturbau (German Association for Water Resources and Land Improvement)
E&SC	Erosion and sediment control
ESCP	Erosion and Sediment Control Plan
GWRC	Greater Wellington Regional Council
HEC HMS	Computer program used to model catchment flows
HY-8	Computer program used to model culverts
KCDC	Kapiti Coast District Council
MBGL	Metres below ground level
M2PP	Mackays Crossing to Peka Peka Expressway
MfE	Ministry for the Environment
RoNS	Road of National significance
NIMT	North Island Main Trunk Railway
NPS	National Policy Statement
NZTA	New Zealand Transport Agency
NZTA SWTS	New Zealand Transport Agency Stormwater Treatment Standard for State Highway Infrastructure
PP20	Peka Peka to North Ōtaki Expressway
Q_{10}	Peak flow for the 10 year average recurrence interval storm or 10% AEP storm event
Q_{100}	Peak flow for the 100 year average recurrence interval storm or 1% AEP storm event
RMA	Resource Management Act
SARA	Scheme assessment report addendum
TOC	Time of concentration
TP	Test pit
USLE	Universal Soil Loss Equation
WRRP	Wellington Region Rail Programme

[1] Flood events are often expressed by their percentage Annual Exceedance Probability (AEP), which is the probability that a particular storm event will be equalled or exceeded in any one year. The same event may alternatively be described in terms of its Annual Recurrence Interval (ARI), the average statistical period between events greater than or equal to the design event. Thus the 1% AEP storm event can also be expressed as the 100 year ARI flood, often shortened to the Q_{100} event.

1 Executive Summary

This report considers:

- the potential stormwater-related effects arising from the Peka Peka to North Ōtaki Expressway Project,
- a proposed package of mitigation measures, and
- an estimation of the residual effects after mitigation.

In our opinion the Project will have a net positive effect on contaminant levels entering the environment, has minimal effects on flood levels and includes proposed culvert details that allow for fish passage.

We have identified the potential stormwater effects of the Project through our own assessment and through consultation. Then we have considered the site conditions and constraints through site visits, geo-technical investigations, hydrological assessments, and topographical assessments.

Through the use of swales and attenuation basins the Project successfully minimises the potential adverse stormwater effects. This is in compliance with industry best practice. Where effects are not fully mitigated we have assessed the residual effects. All new roads will be treated[2], using principally swales or wetlands, however attenuation[3] is proposed for only about 55% of the route length.

The following table gives a brief summary of this process. This report *does not cover* the in-depth flooding assessments undertaken for the Waitohu, Mangapouri, Ōtaki and Mangaone waterways; these each have their own specific modelling report, and are summarised in technical report TR9[4].

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[2] "Treatment" is the generic term applied to measures that reduce or remove contaminants from road runoff. Swales, ponds and wetlands are common examples of treatment.

[3] "Attenuation" is the reduction of peak flows, usually by some form of detention.

[4] *Peka Peka to North Ōtaki Expressway, Technical Report No 9, Assessment of Hydraulic Effects for Major Watercourse Crossings*, (Opus, Nov 2012)

Table 1: Summary of effects

Item	Potential effect	Mitigation through design	Residual effect
Contaminants	Contaminants (brake pad dust, tyres, paint, lubricating oils, exhaust fumes, coolant and oil leaks etc) collecting on the road and washing into the environment.	The proposed new roads are all designed to drain to swales[5] or other treatment devices. The swales filter out the majority of pollutants that the rainwater collects as it runs off the road.	Although the swales can meet the NZTA design standards, they will not remove 100% of the pollutants. This is not practically or economically achievable with current technology. If the Expressway and the existing SH1 are considered together, then this Project has a net positive effect on the amount of pollutants reaching the receiving environment. This is because the majority of existing traffic (associated with the contaminants' generation) will stop using the existing SH1, which has no formal road runoff treatment, and will use the Expressway, all of which will have formal road runoff treatment.
Increased runoff – stream bank erosion (in small frequent rainfall events)	An increased volume of rainwater runs off the new impervious surfaces, as none is lost via soakage or evapotranspiration. Potential increase in stream erosion due to a permanent small percentage increase in stream flow.	International research shows that this effect is only significant if the catchment imperviousness is over 3% (which is not the case for the majority of this Project[6]) However, because it is easy to achieve, the current design proposal provides for extended detention to be provided at all locations (except where discharging to the Ōtaki River or to ground)	None, fully mitigated. The relevant standard is exceeded.
Increased runoff – flood mitigation (in large storm events)	As above, increased runoff due to increased impervious surfaces. Potential increase in downstream flood levels in large rainfall events.	The swales we have designed to provide treatment also provide attenuation for over half the Project length. For the rest of the Project: – the road catchments that discharge to the Ōtaki River or to ground are not attenuated, and – for the remainder, attenuation basins have been included.	No residual impact for all storms up to the Q_{100} event. Whilst no attenuation of storm flows is proposed for areas discharging to the Ōtaki River, the effect on the river is deemed to be insignificant.

[5] "Swales" are shallow channels (usually grass-lined) through which road runoff receives treatment as it percolates through foliage. "Attenuation swales" provide storage and peak-flow attenuation in addition to treatment.

[6] Refer to Appendix 3 for an assessment of catchment imperviousness.

Item	Potential effect	Mitigation through design	Residual effect
Constrictions introduced	By culverting streams, constrictions to flows are introduced. The effect is that water can pond upstream of the culvert. This increase in water level can have a negative effect on adjacent land or buildings	The culverts are designed so that the upstream ponding does not affect upstream flooding levels outside of the designation. We have been able to do this in all cases with the exception of the Gear/Settlement Heights culverts.	Due to downstream constraints, we have not been able to eliminate the effects of increased ponding depth at the Gear/Settlement Heights culverts The residual effect is that the Q_{100} flooding level in the area will increase by approximately 300mm and potentially a farm building would be adversely affected to a greater level than currently.
Constrictions removed	By replacing existing culverts with larger new culverts. The potential effect of this is to allow a greater flow of water downstream in a storm event. This may make existing flood problems worse.	This is difficult to mitigate through design. The only thing that can be done is to keep the existing constriction in place. This might compromise levels of service. Constrictions have been kept in place around the Ōtaki township, but not at the southern end of the Project.	Of the two constrictions that have been removed: one has an additional existing constriction (which is not being removed) just upstream so there is no increase in flow; the other has been assessed to have only impounded a very small amount of water, so the increase in flow is deemed to have a negligible effect, if any, on downstream flood levels.
Extreme (i.e. super-design) event flows	In a storm event greater than the 100 year ARI design event, available Expressway culvert freeboard may be “used up” and the Expressway may overtop. Culvert headwater pond depth and extent may increase, and overland flowpaths may be diverted.	An extreme event (defined as 1.5 times the 100 year ARI storm flow plus climate change) was modelled for each culvert to ascertain whether the Expressway overtops, and the likely location of the overflow path.	Some short-term inundation of the Expressway; some increased depth and extent of culvert headwater ponding (depth increase generally limited to “consumption” of the 500mm culvert freeboard before overtopping occurs); and some diversion of overland flows. Note that this low-probability event lies outside the Project design brief, and therefore some level of effects must be expected. It has been evaluated to ensure that the potential effects are not catastrophic.
Fish passage	Introducing culverts into streams can create barriers to fish migrating. The potential effect of this is that fish will be cut off from their habitat which leads to a decline in fish numbers.	We have estimated low flows (the flows that occur 80% of the time) and have designed the culverts such that native fish are able to swim into and through them. Fish passage features includes: introducing rocky substrate to culvert inverts, rock ramps, and very importantly, setting downstream inverts below low flow ponding levels.	None. Fully mitigated pending attention to detail during construction.

Item	Potential effect	Mitigation through design	Residual effect
Loss of flood plain storage	By road embankment occupying volume in an existing flood plain. The potential effect is increased flood levels.	This can be designed out by altering the route of the road, or offset by creating new flood storage areas where there is land available in the appropriate location.	Altering the proposed road alignment or providing new flood areas has been deemed impracticable in this case. Instead at several locations the effect has been modelled and found to be minor (see Technical Report Nº 9)

It is our professional opinion that the residual stormwater effects of the Expressway, after application of the mitigation measures described herein, will be less than minor, and are acceptable. The sole exception to this is the farm shed at Gear Rd, for which the residual effects are likely to be minor-moderate.

2 Introduction

Opus and URS have been commissioned by the NZ Transport Agency (NZTA) to carry out an assessment of environmental effects (AEE) for the Wellington Northern Corridor Road of National Significance (RoNS) from Peka Peka to North Ōtaki (the Project).

2.1 Author experience and qualifications

The principal author of this report was Warren Bird, with support from Richard Coles. Their experience and qualifications are summarised in the table below.

Table 2: Author's experience and qualifications

Author	Experience	Qualifications
Richard Coles	9 years of experience as a Civil Engineer, recently specialising in stormwater management.	BEng (Civil), MSc (Water Res), CPEng, MIPENZ
Warren Bird	29 years of experience as a Civil Engineer specialising in stormwater management.	BE (Civil), MIPENZ

2.2 Purpose

The purpose of this report is to describe the stormwater aspects of the Project, and provide a professional opinion on the likely extent of the Project's environmental effects associated with stormwater and the most-appropriate means of mitigation.

2.3 Scope

This report recaps on work undertaken in earlier stages and captures the assessment and design work done needed to identify stormwater effects. This report covers:

- design standards and design level of service;
- characteristics of the existing environment;
- effects assessment; and
- recommended mitigation measures and conclusions.

The particular Project elements that this assessment covers are:

- collection and conveyance of road runoff;
- treatment and attenuation of road runoff; and
- small to medium waterway crossings.

This report does not specifically address construction-related effects such as erosion/sedimentation, dust, etc. These are addressed more fully in the *Peka Peka to North Ōtaki Expressway Project Draft Erosion and Sediment Control Plan*[7].

Although closely related, this report does not address large waterway crossings and associated regional flooding issues and flood modelling. These are covered in Technical Report No 9[8]. Other than the hydrology report, this report should also be read in conjunction with Technical Reports No 4[9] No 5[10] and No 12[11].

While the design and effects outlined in this report form the basis of consent applications, the design is expected to undergo further evolution and refinement through subsequent stages of design and construction.

2.4 Project location

The Project is located on the Kapiti Coast adjacent to the existing SH1, extending from the Peka Peka Beach junction to just north of Ōtaki.

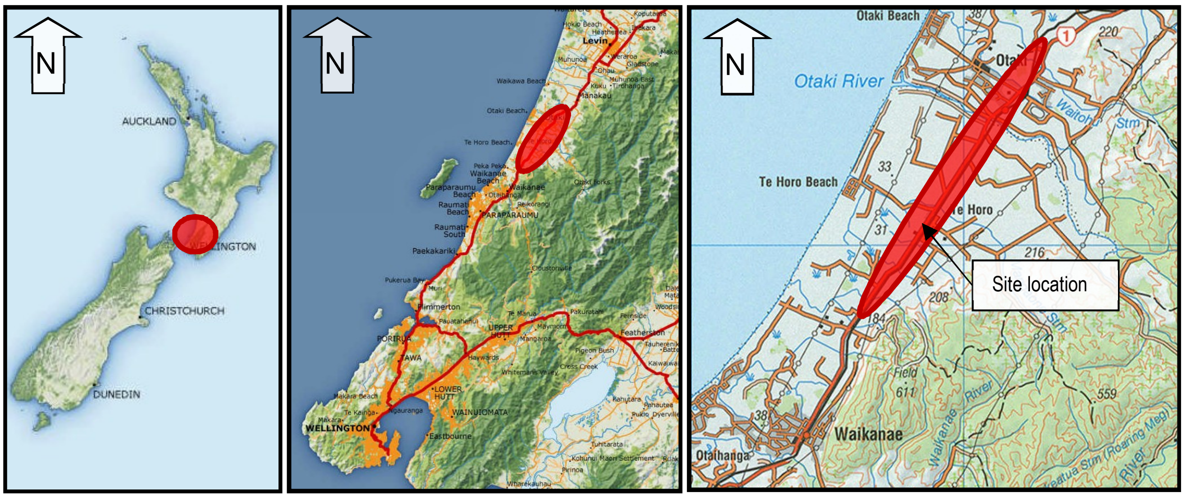

Figure 1: Project Location Maps

[7] *Peka Peka to North Otaki Expressway Project Draft Erosion and Sediment Control Plan*, in Appendix C of the Contractor's Environmental Management Plan (refer Project AEE, Vol 4) (Opus, Nov 2012)
[8] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012
[9] *Peka Peka to Ōtaki Expressway, Technical Report No 4 Geotechnical Report*, Opus, 2012
[10] *Peka Peka to Ōtaki Expressway, Technical Report No 5 Construction Methodology Report*, Opus, 2012
[11] *Peka Peka to Ōtaki Expressway, Technical Report No 12 Aquatic Ecology Assessment*, NIWA, 2012

3 Project Background

A full description to the background of the Project is given in Part 2 of the AEE, however a short description is provided here.

3.1 Peka Peka to North Ōtaki Expressway

The Wellington Northern Corridor RoNS runs from Wellington Airport to Levin. The Peka Peka to North Ōtaki (PP2O) Expressway Project is one of eight sections of the Wellington Northern Corridor RoNS. The location of the PP2O Expressway within the Kapiti Expressway Corridor is illustrated in Figure 1 below.

The New Zealand Transport Agency (NZTA) proposes to designate land and obtain the resource consents to construct, operate and maintain the PP2O Expressway. This Project extends from Te Kowhai Road in the south to Taylors Road just north of Ōtaki, an approximate distance of 13km.

The PP2O Expressway will provide for two lanes of traffic in each direction. Connections to local roads, new local roads and access points over the Expressway to maintain safe connectivity between the western and eastern sides of the Expressway are also proposed as part of the Project. There is an additional crossing of the Ōtaki River proposed as part of the Project, along with crossings of other watercourses throughout the Project length.

On completion, it is proposed that the Expressway becomes State Highway 1 (SH1) and that the existing SH1 between Peka Peka and North Ōtaki becomes a local road, allowing for the separation of local and Expressway traffic.

Figure 2: Location of Peka Peka to North Ōtaki Expressway within the Wellington Northern Corridor RoNS

3.2 Realignment of North Island Main Trunk Railway Line

KiwiRail proposes to designate land in the Kapiti Coast District Plan for the construction, operation and maintenance of a realigned section of the North Island Main Trunk (NIMT) Railway through Ōtaki. This realignment of this section of the railway line is required to facilitate construction of the PP2O Expressway.

4 Existing Environment

This section describes the physical environment of the Project area, including: topographical, geological, man-made and hydrological features.

4.1 Topography

Land either side of the route generally consists of flat land to the west, and steep hill country to the east, with waterways flowing from east to west, towards the sea. Smaller waterways have defined flow paths east of the corridor but some lose definition as they flow across flat land to the west (possibly due to infiltration or diversions to artificial farm drainage channels).

Ground along the corridor has mostly low gradients. The middle third of the route has limited locations where stormwater can be discharged. The northern end (north of Ōtaki Township) rises into rolling country.

The Ōtaki alluvial plain influences the topography significantly. The alluvial plain and steeper hill country is indicated on in image below.

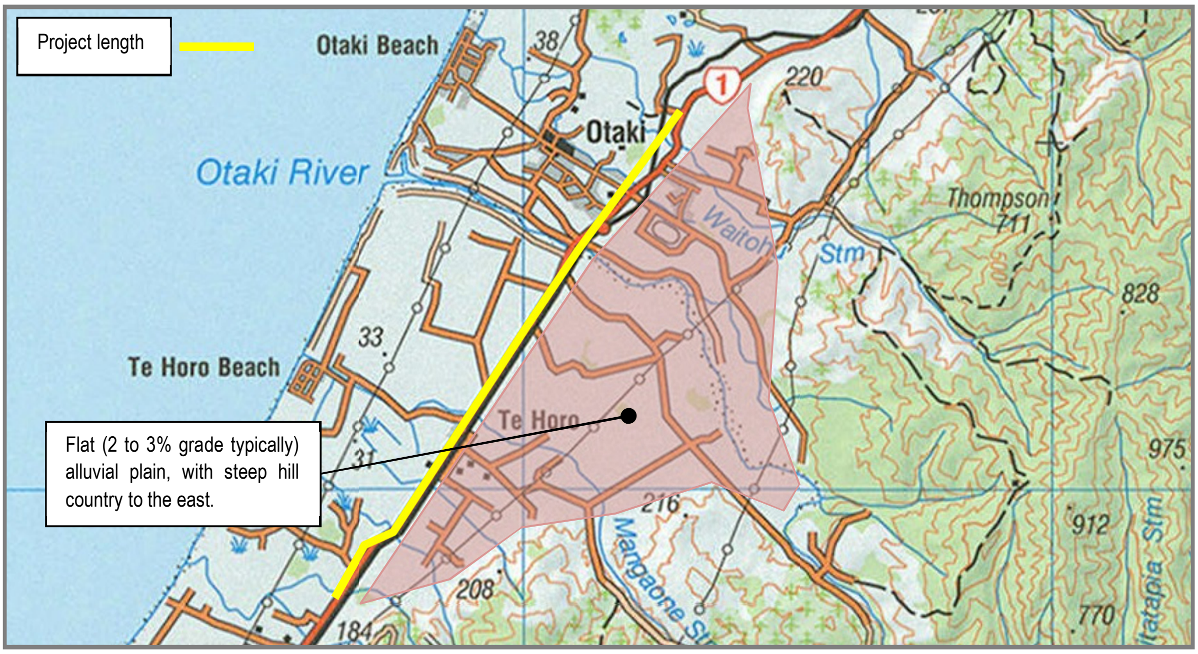

Figure 3: Topography

4.2 Geology

The landform of the Project area is defined by a number of strong natural features including: the coastal edge, the coastal plain, the eastern foothills, and the rivers and streams.

The southern 3km of the Project may be subject to debris flows, due to the small and steep nature of the catchments to the east.

Between Peka Peka Road and Te Horo Beach Road, there are underlying dune sand and inter-dune deposits, which have a high peat content.

North of Te Horo Beach Road, the underlying geology includes terrace alluvium and recent alluvium. Directly north of the Ōtaki River there are river gravel deposits; bore log information indicates that soakage potential in this area is very good.

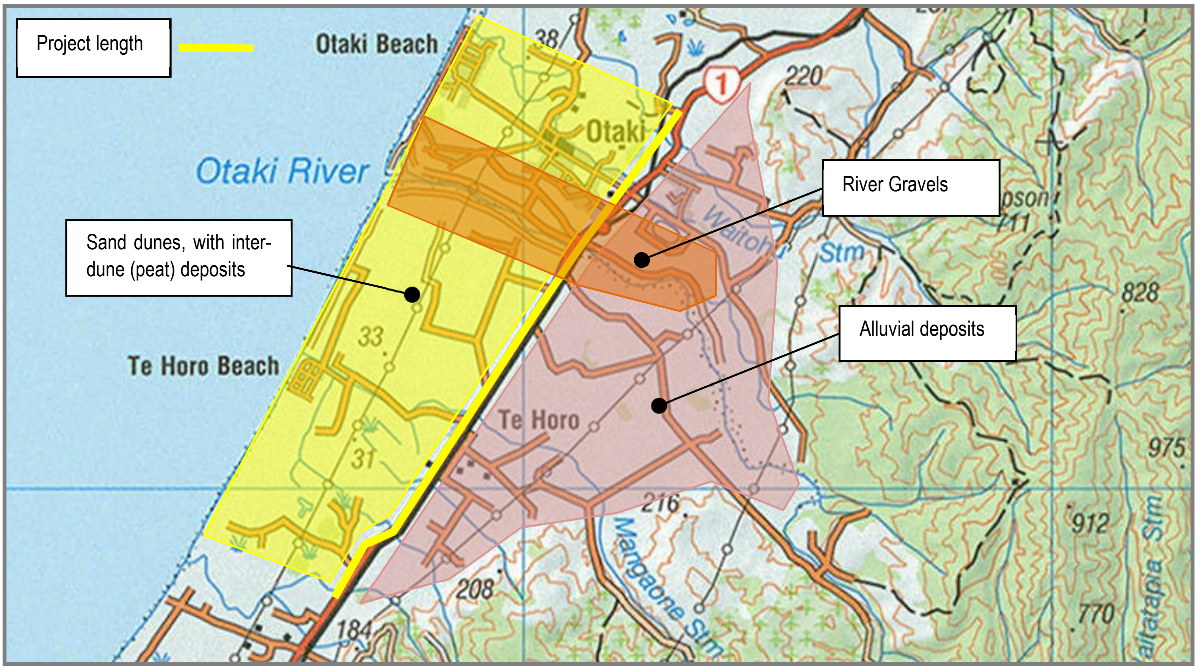

Figure 4: Indicative Geology

4.3 Existing man-made features

The existing SH1 and NIMT rail embankments alter the natural drainage patterns of the area. In isolated places the culverts under the railway act as a restriction, reducing the downstream flooding risk. The existing railway embankment will also serve to contain any debris flows generated in the southern catchments.

Just north of the Ōtaki River is the Ōtaki stop bank, which alters the local drainage pattern, particularly from the north. The stop bank prevents this part of the land having a positive outfall to the Ōtaki River, however the river gravels in this area permit virtually all runoff to discharge to ground.

4.4 Waterways of significance

The three larger waterways noted below are cited in Greater Wellington Regional Council's (GWRC) Regional Freshwater Plan as having special significance. The location of the waterways is shown in Figure 5 below.

Table 3: Waterways of Significance

Waterway	Waterway listed as:
The Ōtaki River	• Containing 'Nationally Threatened Indigenous Fish' (species recorded are: short jawed kokopu, giant kokopu, banded kokopu, and koaro) • Containing 'Important Trout Habitat' • Having 'Important Amenity and Recreational Values'
The Waitohu Stream	• Containing 'Nationally Threatened Indigenous Fish' (species recorded are: brown mudfish)
The Mangaone Stream	• Containing 'Nationally Threatened Indigenous Fish' (species recorded are: short jawed kokopu, koaro, and banded kokopu)

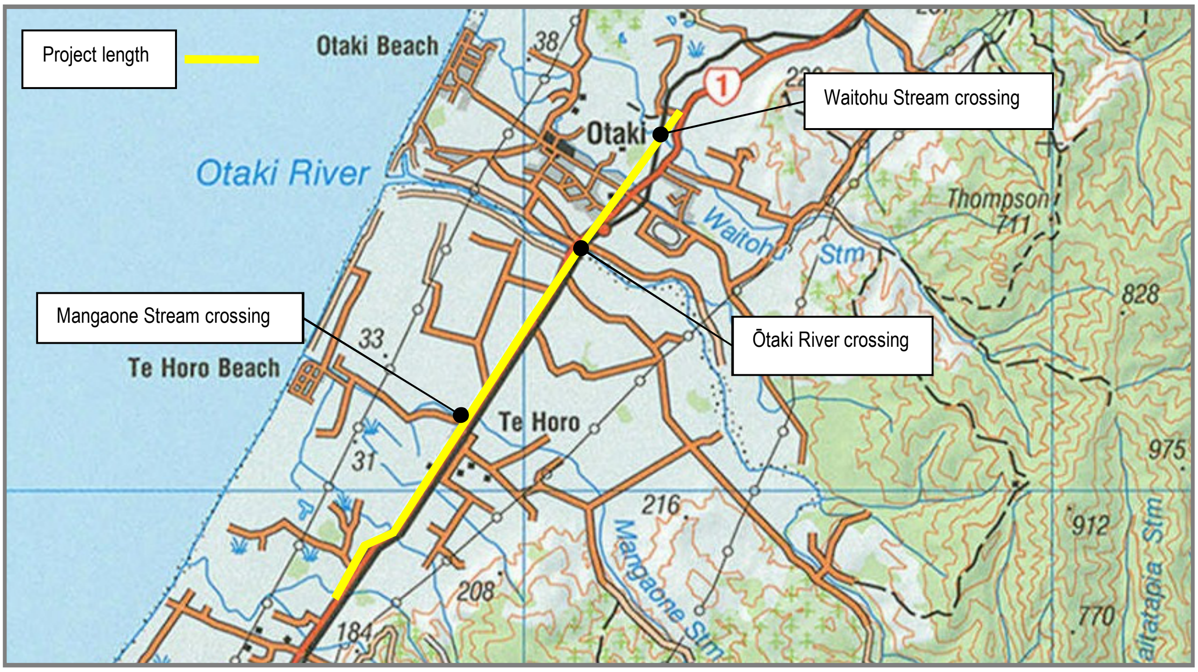

Figure 5: Locations of Waterways of Significance

4.5 Baseline Environmental Monitoring

Preliminary aquatic and terrestrial ecological assessments were conducted as part of the Project, and are reported elsewhere.[12][13] The features of significance identified by those assessments have informed the "best practicable option" approach to stormwater management for the Expressway outlined in this report.

[12] *Peka Peka to Ōtaki Expressway, Technical Report No 12 Aquatic Ecology Assessment*, (NIWA, 2012)
[13] *Peka Peka to Ōtaki Expressway, Technical Report No 11 Terrestrial Ecology Report* (Opus, Feb 2013)

4.6 Stormwater catchment maps

The Project length crosses four major catchments. These are the Waitohu, Ōtaki, Mangaone and Awatea catchments as shown on Figure 6 below.

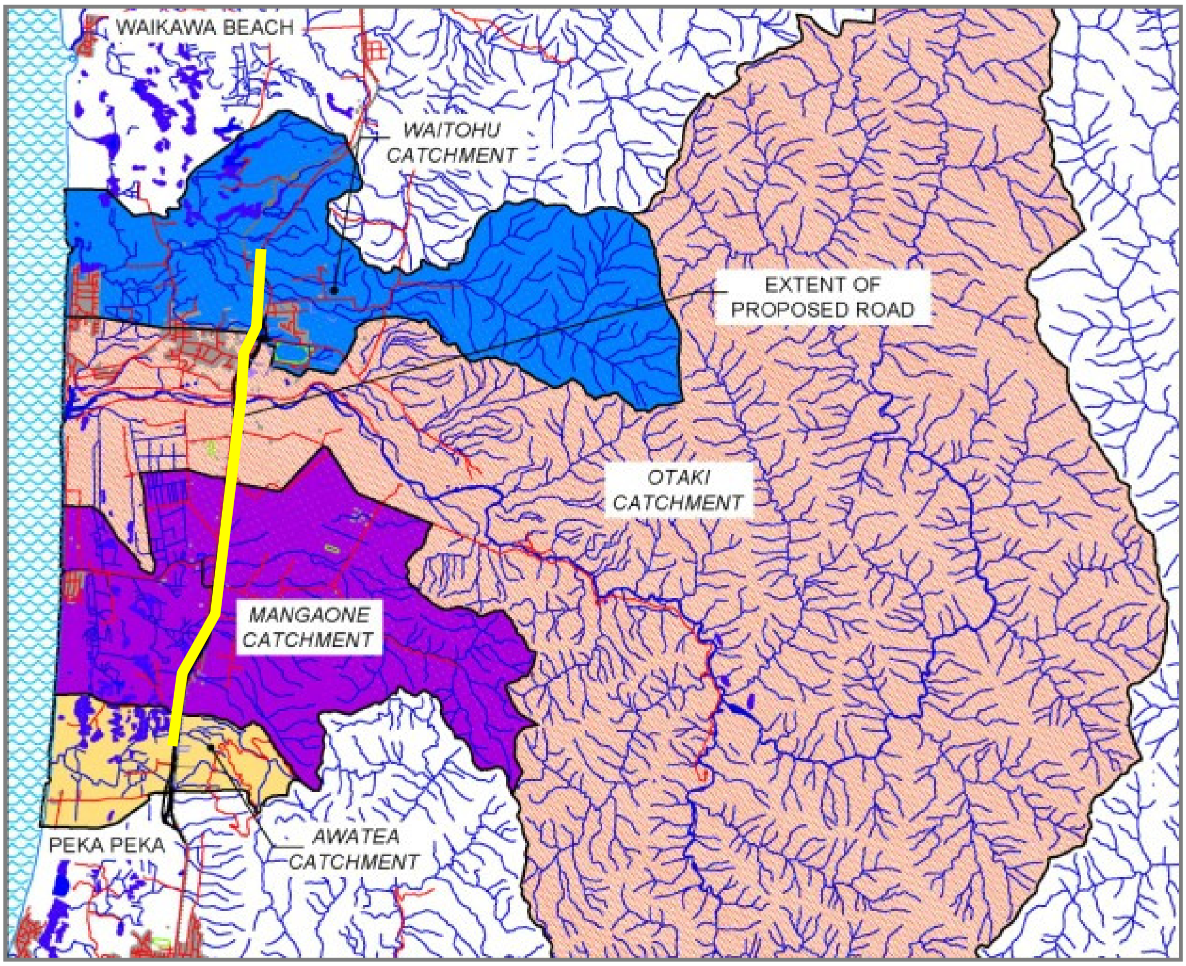

Figure 6: The four major catchments that the Project lies within

4.7 Rainfall

The rainfall patterns across the Kapiti Coast were the subject of a study carried out by SKM and are now included as part of KCDC's Subdivision requirements[14][15] (including the August 2008 updated rainfall analysis).

These rainfall charts have been used in preference to HIRDS V3.0 data because the KCDC charts are based on a specific study for the Kapiti Coast region; whereas the HIRDS rainfall charts are based on a general nationwide study and are principally intended for use where no better location-specific data exists.

[14] *Subdivision and Development Principles and Requirements*, Kapiti Coast District Council, 2005

[15] *Isohyet Based Calculation of Design Peak Flow – Isohyet guidelines and charts*, (produced on behalf of KCDC by SKM, 2005), and *Update of Kapiti Coast Hydrometric Analyses – updated rainfall analysis* (SKM, August 2008)

The 24 hour rainfall depths vary across the Project. For the Q_{100}(2090) nested storm[16], the depths range from 150mm to 165mm along the road. The intensity of rainfall increases from east to west, as it is heavily influenced by the Tararua Ranges. When assessing stream flows from rainfall, the typical rainfall depth at the centre of the catchment has been used (this being a greater rainfall depth than along the road).

4.8 Climate change

The Ministry for the Environment (MfE) has established guidelines when considering potential climate change effects[17]. SKM has incorporated the MfE's climate change recommendations (additional average rainfall of 16.8% for the 24 hour Q_{100} rainfall event – this assumes a mid-range predicted temperature change of 2.1 degrees by 2090 and a 8% increase in peak rainfall intensity per degree of change) into the regional rainfall maps for KCDC. As the KCDC Q_{100} plus climate change to 2090 maps have been used, the effect of climate change is automatically included in the assessments.

With the exception of the Ōtaki River, the Project is far enough inland not to be affected by changes in sea level.

[16] A typical storm event contains many sub-parts of different durations and intensities, each of which can be assigned their own return period. For example, the heaviest 10 minute rainfall may have a return period of 10 years ARI, while the 2 hour component may be a 100 year storm. A nested storm is a design storm profile where all the component parts have the same return period and are assumed to coincide. This is most uncommon in nature, but is used for convenience in design.

[17] *Climate change effects and impacts assessment: A guidance manual for local government in New Zealand*, Wratt D, et al, Ministry for the Environment, 2008, 153p.

4.9 Stream flood flows

The Q_{100} flood flows for the small to medium sized streams have been sized using the U.S. Department of Natural Resources Soil Conservation Service (SCS) method, used in accordance with KCDC's Subdivision requirements. The three significant watercourses (as listed in Table 3) and the Mangapouri stream, have been the subject of specific study and are considered separately in Technical Report No 9[18]. Appendix 1 includes flow calculation inputs and results for the waterway crossings. This includes:

- A map showing all the waterway crossings and their associated catchments;
- KCDC SCS method inputs to HEC HMS model;
- KCDC SCS method outputs from HEC HMS model; and
- Comparison of results between SCS method and regional method.

Table 4: Summary of flood flows

Waterway	Q_{10} flow[19] (m^3/s)	Q_{100} flow (m^3/s)
Greenwood (dist 0,394)	8.6	13.3
Waitohu* (dist 0,825)	-	217
Te Manoau (dist 1,650)	2.0	3.2
Mangapouri (dist 1,940)	-	~ 5
Racecourse (dist 2,195)	1.1	1.8
Te Roto (dist 2,620)	0.6	1.0
Ōtaki* (dist 3,600)	-	2120
Mangaone* (inc. School) (dist 7,250)	-	85.2
Gear (dist 8,610)	6.6	11.0
Settlement Heights (dist 8,910)	12.5	21.1
Coolen (dist 8,980)	0.6	0.9
Avatar (dist 9,370)	3.5	5.7
Jewell (dist 10,020)	17.7	21.8
Cavallo (dist 10,590)	1.3	2.2
Cording (dist 10,930)	0.9	1.4
Awatea (dist 11,335)	8.2	13.7
Kumototo (dist 11,630)	4.0	6.4

* denotes gauged streams with flow records available.

[18] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, (Opus, 2012)

[19] Both the Q_{100} and Q_{10} flows include climate change to 2090 and are assessed at the point the waterways cross the Expressway. Where stream gauging data was available, this was used in preference to other flow assessment methods.

4.10 Stream low flows

Low flows are of interest when considering the design of fish passage through culverts, and associated effects. Low flows are commonly defined internationally as the 10th to 90th percentile flows[20]. This gives engineers an upper and lower bound flow to consider when designing fish passage features, and acknowledges that it is unrealistic to expect fish migration (or passage through the culverts) when the flow is tending towards non-existent or approaching flood conditions. In essence this approach enables fish passage for approximately 300 out of 360 days per year, or for 80% of the time.

The 10th and 90th percentile flows have been assessed by scaling the flow record from the Mangaone Stream, adjusting as a function of differences in Mean Annual Flood (MAF) obtained from the REC (River Environment Classification). This approach includes consideration of the effects of both area and rainfall variability across the catchment. This was done for streams where fish passage was potentially needed through a culvert. Bridged streams generally do not provide any barrier to fish migration.

A memo further documenting this assessment is included in Appendix 2. The 10th and 90th percentile flows are summarised in the table below.

Table 5: Summary of low flows

Waterway	10th percentile flow (l/s)	90th percentile flow (l/s)
Greenwood	10	71
Waitohu	223	2060
Mangapouri	14	99
Mangaone	187	1296
School	14	95
Gear	16	113
Settlement Heights	26	176
Jewell	30	206
Awatea	22	154
Kumototo	8	57

[20] *DVWK Fish passes – Design, dimensions and monitoring*, 2002, FAO, United Nations.

5 Stormwater Related Potential Effects

The possible stormwater-related environmental effects of building a new road, re-aligned railway, and connecting roads can be considered in three groups. The first group includes effects arising during the course of construction activities. The second group are associated with the impermeable nature of the road pavement and the pollutants that are generated on it. The final group of effect are due to the road/railway crossings of waterways, which can disrupt natural flow patterns and habitat. These potential effects are described below.

5.1 Construction-Related Effects

Erosion/Sedimentation

During the course of construction large areas of earth will be exposed as part of earthworks activities. This raises the potential for erosion of bare soil and contamination of water bodies with sediment. This is a particular risk during the course of bridge/culvert construction, stream diversions, and any other work in close proximity to streams. Construction-related erosion/sedimentation is not addressed directly in this report, but is comprehensively covered in the *Draft Erosion and Sediment Control Plan*.[21]

Dust

Similarly dust can be mobilised by earthworks and spread by wind where it creates both human nuisance and potential environmental effects. Dust control is also covered in the *Draft Erosion and Sediment Control Plan.*

5.2 Road surface-generated effects

Contaminants (from road surface)

Pollutants generated by vehicles will accumulate on the road surface and then get washed off by rain. With no intervention, the pollutants will be washed into the surrounding environment, which could be the surrounding land but is often streams. The effect of these contaminants on a stream is small but cumulative.

The commonly-accepted mitigation for this is to remove the majority of the contaminants from the rainwater before it discharges to streams or reaches ground water (the receiving environment).

A recent study[22] by Earl Shaver (recognised stormwater industry expert) and Alastair Suren (NIWA), showed that road runoff has little effect on invertebrate communities in receiving streams (that is to say that the effect was not measurable using invertebrate communities as an indicator). It should be noted that the locations tested were for typical road conditions

[21] *Peka Peka to North Otaki Expressway Project Draft Erosion and Sediment Control Plan*, in Appendix C of the Contractor's Environmental Management Plan (refer Project AEE, Vol 4) (Opus, Nov 2012)

[22] *Assessing Impacts of State Highway Stormwater Runoff on Stream Invertebrate Communities*, NZTA, 2011 (ISBN 978-0-478-38069-9)

and the runoff did receive a level of informal treatment as it flowed through the existing open drains.

> *"The salient results of this study were that invertebrate communities in the five of the six streams monitored[23] showed little evidence of being affected by runoff from state highways, despite high traffic densities, and despite the fact that all the streams sampled were in good ecological condition and unaffected by stresses associated with urban runoff. Changes to the invertebrate communities in the other stream (Smith Creek) as a result of road runoff were regarded as minor, at most. Likely reasons behind the lack of a strong consistent signal of road runoff most likely reflects a combination of the generally smooth-flowing vehicle behaviour resulting in lower emissions, and the presence of vegetated roadside drains that road runoff flowed into that minimised the direct conveyance to the streams and potentially reduced contaminant loads."*[24]

Increased runoff in small frequent rainfall events (from road surface)

On green-field development (as the Project is) the existing ground is often pasture. When it rains, some of the water soaks into the ground and some is lost through evapotranspiration (by plants), leaving only a portion to run off the land into streams. The natural form of the stream reflects the amount of runoff from the land that naturally occurs.

When a road is built, the rain that falls on the pavement is unable to soak into the ground or be lost through evapotranspiration (as the road surface is impervious) and virtually all the rain turns into runoff. This means that more water reaches the streams that the road crosses, often faster as a result of efficient drainage systems. This in turn increases stream erosion and changes the stream characteristics (or speeds up the rate of change).

The effects of this are small but incremental. If the total catchment of a stream has less than 3% impervious surface then the stream is likely to be able to absorb the increase in flow without significant negative effects[25]. However once this 3% threshold is exceeded, mitigation is required.

The usual mitigation for this is to provide storage areas that, during small rainfall events, can hold back water and release it slowly once the rain has passed.

Increased runoff in large infrequent storm events (from road surface)

As described above, building a road on a green-field site increases the runoff. In large storm events there is likely to be flooding in the natural system. The increased road runoff is likely to make this flooding worse (ie increased downstream flood levels), depending on timing effects.

Once again the effects of this are small but incremental. The usual mitigation for this is to provide storage areas that, during large storm events, can hold back water and release it slowly once the peak of the storm has passed.

[23] One of the streams assessed lies within the PP2O project length.
[24] ibid, p.3
[25] *Stormwater Treatment Standard for State Highway Infrastructure*, (NZTA, May 2010), section 7.1.3

5.3 Effects associated with waterway crossings

Increases in upstream culvert ponding levels (at stream crossings)

The Project has more than 25 crossing points over waterways ranging in size from the Ōtaki River to minor land drains.

When a road crosses a drain, stream or river the waterway can be diverted, culverted, or bridged. When the waterway is bridged there is relatively little stormwater environmental effect (assuming the bridge is sufficiently wide and the bed is not unduly disturbed during construction). Diverting a waterway is typically only done to low ecological value land drains or where the alignment unavoidably runs near-parallel with a watercourse (which is not the case on the Project except over short lengths). The most common way for a road to cross a waterway is to culvert the stream.

A feature of culverts is that there needs to be a difference in water level between the upstream end and the downstream end for any water to flow through them. In large storm events this means that the level of the water in the stream has to build up to push water through the culvert. This increase in water level (and wetted area) can cause a negative effect on the adjacent land or buildings. Ideally the culvert should be sized so that the increase in upstream water level will be kept within the road designation or within the natural banks of the stream. Sometimes this is not practicable and the increased water level is allowed to spread to rural land if the effect is deemed sufficiently minor.

Removal of existing constrictions (at stream crossings)

Existing roads and railways have existing culverts. When these roads are upgraded the culverts are often upgraded also. Typically the new culverts are bigger than the existing culverts (as levels of service rise and climate change is considered). This can mean that during large storm events water that was held back by the previously small culvert (acting as a constriction) is not held back by the new larger culvert.

This can mean that the peak flow in the waterway downstream of the upgraded culvert can be higher than it was previously. Depending on the magnitude of water that was previously impounded and the scale of the increase in peak flow, this can make existing downstream flooding worse.

One potential mitigation option is to keep the existing constriction in place. Alternatively, minor increases in flow may be tolerated if they are considered to have a minor effect.

Creating barriers to fish migration (at stream crossings)

If culverts are designed and constructed only considering the flood flow hydraulics, then barriers to fish passage can be inadvertently created. The potential effect of this is that fish will be cut off from their habitat, which leads to a decline in fish numbers.

The appropriate mitigation for this is to consider low flows and design the culvert such that native fish are able to swim into and through the culvert.

Reduction of existing flood storage (at stream crossings)

Where new roads (particularly roads on embankments) are built through existing flood areas, the embankment takes up volume that would previously be available for ponding of flood water. The effect is that the flood levels rise slightly. The amount the flood level rises by depends on the extent of the flood area and the volume that the road takes up below the water level. Generally speaking, the larger the flood area the smaller the effect.

One mitigation option is to excavate additional land within the flood area to offset the flood volume removed by the new road. Alternatively the effect on flood level may be shown to be insignificant by analysis (e.g. hydraulic modelling).

When undertaking stormwater management for any type of development it is seldom practicable to eliminate all effects entirely. Therefore, internationally, a best practicable option approach is usually adopted to achieve an optimal balance between the cost of mitigation and the severity of residual effects. The next chapter outlines stormwater design standards adopted for the Project. It also describes the site conditions and constraints that the solution has to work within. Subsequent chapters describe how the majority of potential effects have been mitigated through good design and by application of a best practicable option, and then outline the expected degree of residual effects.

6 Design Setting: Standards, Levels of Service and Constraints

Although this report is focused on effects, this section covers previous work done, particularly the consultation and determining appropriate levels of service carried out at the SARA stage of the Project.

This section also goes on to give a general description of the site at specific locations, to set the scene and give the constraints that influenced the potential effects, the proposed mitigation and the ability to mitigate the effects fully.

6.1 Documents

The key design and reference stormwater documents are:

6.1.1 NZTA documents

- Highway Surface Drainage, NZTA, 1977.
- Bridge Manual Second Edition, NZTA, 2003 (and amendments 2004, 2005).
- Environmental Plan, NZTA, 2008.
- Stormwater Treatment Standard for State Highway Infrastructure, NZTA, May 2010.
- HNO Environmental and Social Responsibility Manual, NZTA, 2012.
- Draft Erosion and Sediment Control Standard for State Highway Infrastructure, NZTA August 2010.
- Assessing Impacts of State Highway Stormwater Runoff on Stream Invertebrate Communities (Submitted by Earl Shaver (Aqua Terra International Ltd.) and Alastair Suren (National Institute of Water and Atmospheric Research Ltd.)), NZTA, 2011

6.1.2 Kapiti Coast District Council (KCDC) documents

- Subdivision and Development Principles and Requirements, KCDC, 2005.
- Isohyet Based Calculation of Design Peak Flow – Isohyet guidelines and charts, SKM (produced on behalf of KCDC), 2005.
- Update of Kapiti Coast Hydrometric Analyses – updated rainfall analysis, SKM, August 2008.
- Stormwater Management Strategy, KCDC, 2009.

6.1.3 Greater Wellington Regional Council (GWRC) documents

- Ōtaki Flood Management Plan, GWRC, 1998.
- Regional Freshwater Plan for the Wellington Region, GWRC, 1999.[26]
- Erosion and Sediment Control Guidelines for the Wellington Region, GWRC, September 2002 (update pending).
- Fish-friendly culverts and rock ramps in small streams, GWRC, 2003[27].

[26] Including plan changes 1 to 5, updated January 2012.
[27] Requirements for provision of fish passage are not currently addressed under the Regional Plans; however the Freshwater Fisheries Regulations still apply. Provision of fish passage is expected by GWRC and is routinely a condition of consent.

6.1.4 Other documents

- TP131 Fish Passage Guidelines for the Auckland Region, ARC, 2000.
- TP10, Stormwater Management Devices: Design Guidelines, ARC, 2003.
- Specification for the installation of pipelines on railway land, Ontrack, 2007.
- Draft Drainage Design Guidelines, Ontrack, January 2008.
- Track and civil design parameters summary, Opus/Ontrack, 2008.
- TP366 Culvert Barrel Design to Facilitate the Upstream Passage of Small Fish ARC, 2008.
- TR2009/084 Fish Passage in the Auckland Region ARC, 2009.

6.2 Consultation

During 2010 and 2011 we had a series of meetings and communications with KiwiRail, KCDC and GWRC to develop an appropriate design philosophy.

6.2.1 Consultation with KiwiRail 2010

During 2010, there were discussions with Mark Gullery and Richard Justice of KiwiRail regarding stormwater standards/design parameters. The conclusion was that KiwiRail's latest stormwater standards are those as agreed on the Wellington Region Rail Programme (WRRP) MacKay's to Waikanae Double Tracking project (see Appendix 3).

6.2.2 KCDC Stormwater Meeting 26 August 2010

Opus had a stormwater focused meeting with KCDC on 26 August 2010. The critical outcomes of the discussions with KCDC are summarised below.

- KCDC advised that GWRC are responsible for water quality.
- KCDC agreed that the general approach would be to: treat runoff from all new impervious areas, with no retrofit of existing roads, in general.
- KCDC are considering whether the NZTA Stormwater Treatment Standard meets their expectations for stormwater treatment. They consider that some catchments may warrant a higher standard of treatment than provided by the NZTA Standard, but have not provided supporting evidence at this stage.
- KCDC advised that acceptable approaches for peak flow attenuation are to attenuate to pre-development levels or establish a case that effects are no more than minor.
- KCDC does not generally favour multi cell culverts on its road network due to the perceived maintenance requirement.
- The Mangapouri Stream is throttled by a culvert under the railway (possibly to 10 or 20 year flow). KCDC are keen to retain this throttle. Any new or re-configured throttle should have an easement over it in to allow KCDC access.

6.2.3 GWRC Stormwater Correspondence 2010

The outcomes of discussions with GWRC are summarised below:

- Flooding from the Waitohu Stream is frequent.
- The waterways that GWRC maintain in the Kapiti Coast that are relevant to the Project are: Ōtaki River, Mangaone Stream, Mangaone Drains, Mangapouri Stream and the Waitohu Stream.
- The Regional Freshwater Plan (RFP) allows stormwater discharge as a permitted activity and there are currently no post-construction stormwater treatment guidelines. However the RFP is soon to be reviewed and GWRC see NZTA as a key stakeholder when it comes to the development of roading-related stormwater provisions. While the outcome of the review cannot be anticipated, it is prudent to assume that GWRC's stormwater discharge requirements will take a step towards the NZTA Standard approach.
- GWRC's expectations are that fish passage be maintained in any permanently flowing watercourses as a minimum. The RFP provides for river crossings in intermittently flowing streams as a permitted activity provided certain conditions are met; it does not require provision for fish passage[28]. Rule 25 specifies the maximum stream catchment size for crossings to be considered as intermittent streams (50ha in the Project area); it does not dictate whether a stream is permanently or intermittently flowing, or the need to provide fish passage.

6.2.4 KCDC Stormwater Meeting 8 April 2011

Opus had a second stormwater-focused meeting with KCDC on 8 April 2011. The critical outcomes of the discussions with KCDC are summarised below:

- KCDC (SKM) advised with regard to Racecourse Catchment, that there is a pipe under County Road and the NIMT but entry and exit points are very overgrown and are suspected to be completely choked. It is likely that the excess water ponds in Racecourse Catchment and soaks away.
- KCDC advised that their preferred approach would be for Opus to demonstrate that 5yr and 100yr storm runoff from the proposed road would be no worse than pre-development runoff, on the basis that the NZTA Stormwater Treatment Standard does not require attenuation.
- In regard to extended detention and stream erosion control, KCDC advised that they do not require detention of stormwater from small storm events but that Opus may choose to follow NZTA practice.
- KCDC advised that background testing may be required if the receiving environment is sensitive, in order to verify that post-development conditions are no worse.

6.2.5 GWRC Stormwater Meeting 15 June 2011

Opus had a stormwater-focused meeting with GWRC on 15 June 2011. The critical outcomes of the discussions with GWRC are summarised below:

- GWRC advised Opus of the contact details for the GWRC person who has responsibility for water quality (subsequent discussions with Tim Park confirmed that

[28] Requirements under The Freshwater Fisheries Regulations (1983) still apply.

the residual bush and associated wetland at Mary Crest is the principal area of concern).

- GWRC requested consideration of an extreme (i.e. super-design) design event, which they defined the as 1.5 x (Q_{100}+CC) flow.
- GWRC advised that if pond volumes did not include extra capacity for climate change, trigger levels may be needed to indicate when the attenuation ponds needed to be made bigger.

6.2.6 KCDC Stormwater Meeting 15 June 2011

Opus' third stormwater-focused meeting with KCDC was on 15 June 2011. The critical outcomes of the discussions with KCDC are summarised below.

- KCDC advised that all developments are required to be hydrologically neutral in terms of peak runoff contribution to local watercourses, and confirmed that KCDC standard is to attenuate Q_{100} flows to 100% of pre development flow.
- KCDC advised that the Mary Crest area is main area of interest from a water quality/ecological perspective.
- KCDC agreed that there will need to be an agreement between NZTA and KCDC on maintenance of the swales that service both NZTA and KCDC roads.
- KCDC advised that the Alliance on the Mackay's to Peka Peka project are using 1.5 x (Q100+CC) as their extreme design event. Opus agreed to consider the same approach.

6.3 Stormwater standards

The above documents and consultation outcomes have been condensed into a single summary table (refer Table 6, below).

Table 6: Stakeholders' Stormwater Standards

	KCDC (from documents)	KCDC (from consultation)	NZTA	GWRC	KiwiRail
Primary drainage	Q_{10}[29]	No further comment	Q_5 to edge of trafficked lane[30] Q_{10} catchpit and pipe capacity	Not specified	Q_{10} with no surcharging[31]
Secondary drainage	Q_{100}[29]	No further comment	In the Q_2 storm event, at least half a traffic lane should have no more than 100mm of surface water depth[30]	Not specified	Q_{100} with minimum 300mm freeboard from rail track[31]

[29] *Subdivision and Development Principles and Requirements*, KCDC, 2005
[30] *Highway Surface Drainage*, NZTA, 1977
[31] *Draft Drainage Design Guidelines*, Ontrack, January 2008

	KCDC (from documents)	KCDC (from consultation)	NZTA	GWRC	KiwiRail
Flood Attenuation - (Storm peak discharge control)	Q_{10} no increase in flows or less than minor adverse efects[29]	either provide attenuation to pre-development level or establish a case that effects are no more than minor	Q_{100} limited to 80% of predevelopment flow (where existing downstream problems exist)[32] (but no attenuation recommended where the project is in the bottom half of the catchment) Q_2 and Q_{10} flows to match pre development flows[32]	Not specified	Not specified
Stream channel erosion control	Not specified	No further comment	Three different approaches: • Check the Q_2 stream velocities to ensure that velocities are non-erosive • Implement extended detention or volume control • Conduct a shear stress analysis for a specific site NB: only applies where catchment imperviousness is expected to exceed 3% (including future foreseeable development) [32]	Not specified	Not specified
Treatment of road runoff	Best Practicable Option (BPO) approach[29 & 33]	KCDC are reviewing NZTA Stormwater minimum standard	BPO aproach[32]. Treat all new impermeable surfaces (or equivalent area).	Not specified	Not specified
Waterway crossings (at culverts)	Q_{10} typically but Q_{100} if appropriate (to be assessed on case by case basis)[29]	Existing level of service not to be reduced.	Q_{100}, with 500mm freeboard[34]	Not specified	Q_{10} with no surcharging and Q_{100} with min 600mm freeboard to rail tracks[31]
Climate change	Best practice (as MfE guidance)[35]	Use of MfE guidelines (or use of SKM rainfall charts also accepted)	Apply to assets lasting longer than 25 years[36]	Best practice (as MfE guidance)	Not specified
Loss of floodplain storage	Not specified	establish effects are no more than minor by modelling or provide compensatory storage	Not specified	Not specified	Not specified
Sediment and Erosion control (during construction)	Not specified	No further comment	As per NZTA draft Standard [37]	As GWRC guidelines[38]	Not specified

[32] Stormwater Treatment Standard for State Highway Infrastructure, NZTA, May 2010
[33] TP10, *Stormwater Management Devices: Design Guideline Manual*, Auckland Regional Council (ARC), 2003
[34] *Bridge Manual* Second Edition NZTA, 2003
[35] *Stormwater Management Strategy*, KCDC, 2009
[36] *Stormwater Treatment Standard for State Highway Infrastructure*, NZTA, May 2010, p55
[37] *Draft Erosion and Sediment Control Guidelines for State Highway Infrastructure*, NZTA August 2010.
[38] *Erosion and Sediment Control Guidelines for the Wellington Region*, GWRC, September 2002

	KCDC (from documents)	KCDC (from consultation)	NZTA	GWRC	KiwiRail
Fish passage requirements	Not specified	No further comment	Not specified	As GWRC guidelines[39]	Not specified

Clearly, there is significant variation in the stakeholders' design standards/expectations. Appendix 3 contains a more in-depth assessment of these expectations, from which we conclude:

- NZTA's Stormwater Treatment Standard does not require any attenuation for the Project, other than mitigation of natural storage lost to the Project works.
- NZTA's Stormwater Treatment Standard requires extended detention (for stream erosion control) for sections of the Expressway discharging to the Waitohu and Awatea catchments but not the Mangaone or Ōtaki catchments.
- KCDC require peak flow attenuation up to the Q_{100} storm event for all locations except where it can be clearly shown that attenuation is not needed.
- KCDC do not require extended detention for erosion control purposes.
- KCDC's stormwater treatment requirements will generally be met by following NZTA's stormwater standard.
- GWRC's requirements will generally be met by application of their applicable guidelines.

6.4 Proposed Project levels of service

After consideration of the various stakeholder standards/expectations we developed a set of stormwater objectives that are proposed to be applied to this Project. In general our proposal is equivalent to the highest reasonable stakeholder standard applicable to each area. Note that these objectives are based on a best practicable option approach, rather than seeking to achieve zero environmental effects.

Our assessment of the NZTA's Stormwater Treatment Standard (see detailed assessment in Appendix 3) showed that no attenuation is required, as the cumulative effects of ongoing catchment development are expected to be minor. Despite this we have adopted the KCDC standard and will be providing Q_{100} peak attenuation to 100% of the predevelopment flow in the locations where required.

As the 2010 NZTA Stormwater Treatment Standard was prepared by a recognized stormwater expert (and underwent implementation testing and formal industry consultation), we believe (and this was provisionally accepted by KCDC in initial consultation) that the 2010 NZTA Stormwater Treatment Standard reflects the latest in stormwater treatment research and thinking. As such, compliance with the NZTA Stormwater Treatment Standard has been adopted as the base-line standard which will also comply with the KCDC's own stormwater treatment requirements.

[39] *Fish-friendly culverts and rock ramps in small streams*, GWRC, 2003

Table 7: Proposed levels of service for new sections of road[40]

	New sections of local and connecting roads	New sections of Expressway and junctions
Earthworks	Apply GWRC's and NZTA's standards jointly – adopting whichever is the more onerous for a given situation	
Climate change	Apply the midrange of the MfE guidance for the year 2090. This is an additional 16.8% of rainfall for the Q_{100} storm event. This has already been incorporated into the KCDC rainfall charts	
Primary road drainage	Designed to convey the Q_{10}[41], 10 minute storm event flows	Designed to convey the Q_{10}, 10 minute, storm event and to keep the Q_2, 10 minute, storm event flows no more than 4mm deep[42]
Secondary road drainage	Assuming no median barrier exists: Minimum of 2m width in centre of road to be passable[43] in a Q_{100}[41] storm event	Assuming a median barrier exists: Minimum of one lane in each direction to be passable[43] in a Q_{100}[42] storm event
Treatment of road runoff	We propose to treat a road surface area, equivalent to the increase in impermeable road surface. However where it is practicable to do so, we will consider treating all road surfaces Treatment to NZTA requirements (which are an evolution of the TP10[44] treatment requirements as referred to in KCDC's subdivision requirements[45]). This is a best practicable option approach and typically aims to remove 70-80% of suspended solids on a long term average basis. NZTA treatment requirements are defined in their Stormwater standard[46] From the NZTA Stormwater standard, the water quality event is defined as 19mm[47] over 24hours (before allowing for climate change)	
Stream channel erosion control (extended detention)	Not required (based on GWRC and KCDC standards)	Where the catchment is expected to achieve an imperviousness of greater than 3%, then provide attenuation to the Q_2 storm event[48].
Flood Attenuation (storm peak discharge control)	For the critical duration storm event for the whole catchment: post road construction Q_2, Q_{10} and Q_{100} storm flows will generally be attenuated to 100% of pre road construction flows. Climate change provision to be incorporated in post-construction flow estimates. [49]	

[40] These are minimum levels of service. The design may in some instances exceed these levels.
[41] *Subdivision and Development Principles and Requirements*, KCDC, 2005
[42] *Highway Surface Drainage*, NZTA, 1977
[43] "Passable" is defined as 100mm of water depth (NZTA 1977) with a velocity not exceeding 2m/s.
[44] TP10, *Stormwater Management Devices: Design Guidelines*, Auckland Regional Council (ARC), 2003
[45] *Subdivision and Development Principles and Requirements*, KCDC, 2005
[46] *Stormwater Treatment Standard for State Highway Infrastructure*, NZTA, May 2010
[47] The NZTA stormwater guidance document defines the water quality event as the 90th percentile rainfall event. From Appendix A of the NZTA stormwater guidance document the 90th percentile rainfall event along the project length varies between 17.5 and 20mm over 24 hours; we have adopted 19mm throughout (not including climate change)
[48] From our *Interpretation of stakeholders' stormwater standards* memo included in Appendix 3, extended detention is only needed where we are discharging at the Greenwood, Mangapouri, Awatea and Kumototo culverts and to the Waitohu Stream. The current design proposal exceeds this minimum standard.
[49] This level of service is the peak flow attenuation standard upon which consent applications will be based. Notwithstanding this, a future designer or design-build contractor could carry out sufficient additional modelling or investigation to build a case that increases in flow are no more than minor for several of the larger catchments (e.g. the Ōtaki River, the Mangaone Stream, the Waitohu Stream and the Mangapouri

	New sections of local and connecting roads	New sections of Expressway and junctions
Minor Waterway crossings[50]	To convey Q_{10} storm flows, typically but 1% if appropriate (to be assessed on a case by case basis)[45] with 300mm freeboard from road edge line	To convey Q_{100} storm flows, with a minimum 500mm freeboard from road white edge line and a maximum of 2m heading up from the culvert soffit
	Hydraulic exceptions are culverts providing a throttling action and flood protection to downstream properties. Design flows will include an allowance for climate change. Fish passage provided to GWRC guidelines[51]	

Following on from Table 7 where basic levels of service are defined, Table 8 was developed, which seeks to define the hydraulic design parameters for the various stormwater elements of the Project. The final stormwater management is not restricted to the elements covered in Table 8 and other devices (including proprietary devices) may be used.

Table 8: Proposed parameters for stormwater elements in new road sections

	New KCDC local roads	New NZTA Expressway
Road surface (Road drainage)	Hydraulic parameters: • No specific objective	Hydraulic parameters: • Maximum pavement water depth 4mm in a 10 minute, Q_2 storm event (this parameter relates to the control of sheet flow for vehicle safety reasons, to prevent aqua-planing)
Kerb and channel with catchpits[52] (Road drainage)	Assumption: • Local roads will have shoulders less than 2.5m wide Hydraulic parameters: • No specific objective to keep channel flow out of trafficked lanes • In a 10 minute Q_{100} storm event, at least 2m of carriageway is to remain passable[53]	Assumption: • The Expressway will have shoulders of minimum width 2.5m Hydraulic parameters: • Keep channel flow, to a maximum of 4mm depth at the edge of trafficked lanes in a Q_{10} storm event (i.e. ensure that longitudinal flow in channels does not encroach onto traffic lanes and become an aqua-planing risk) • In a 10 minute Q_{100} event, at least one lane is to remain passable[53]

stream). Besides technical justification, any modified approach would need to be supported through consultation and potentially consent variations.

[50] Minor waterway crossings refer to all waterway crossings with the exception of the four major crossings (Ōtaki, Waitohu, Mangaone, Mangapouri).

[51] *Fish-friendly culverts and rock ramps in small streams*, GWRC, 2003

[52] The generic term "catchpit" is used here to describe a variety of devices for the capture of surface water into a pipe, and includes proprietary products.

[53] "Passable" is defined as 100mm of water depth (NZTA 1977) with a velocity not exceed 2m/s.

<table>
<tr><th></th><th>New KCDC local roads</th><th>New NZTA Expressway</th></tr>
<tr><td></td><td colspan="2">Catchpit capacity designed for the 10 minute, Q_{10} storm event flows (allowing for 50% blockage for catchpits on grade and 70% blockage for catchpits in a low point)
Catchpit capacity to be designed for the 10 minute, Q_{100} storm event flows (allowing for 50% blockage for catchpits on grade and 70% blockage for catchpits in a low point) where no secondary overflow path exists
Climate change to be applied to all flows
Physical parameters:
Catchpit leads to be lower than incoming subsoil drains
Catchpit sumps[54] to be 0.6m minimum depth below invert of catchpit lead
Catchpit grates to be minimum size of 450mm by 650mm and to be high capacity (such as Manning grates) - cycle friendly grates only required where shoulders are less than 1.5m (such as the Humes 675mm x 450mm cycle friendly grate)
Catchpits to have a back entry lintel[55] 2.4m minimum length</td></tr>
<tr><td>Median
(Road drainage)</td><td colspan="2">Assumption:
Required where a four lane road in super elevation
Median drains provide conveyance only (is no formal treatment or detention).
Hydraulic parameters (As Kerb and channel above).
Physical parameters:
Expected to be low vegetated drain with catchpits (catchpit parameters as above)
Catchpits to discharge to adjacent swales at the edge of the road.</td></tr>
<tr><td rowspan="3">Pipework
(Road drainage)</td><td colspan="2">Hydraulic parameters:
Catchpit leads and mainline pipework designed for the 10 minute, Q_{10} storm event flows
Pipe work to be designed for the 10 minute, Q_{100} storm event flows where no secondary overflow path exists
Climate change to be applied to all flows</td></tr>
<tr><td>Physical parameters:
Minimum size of catchpit leads and pipe, 225mm diameter</td><td>Physical parameters:
Minimum size of catchpit leads and pipe, 300mm diameter</td></tr>
<tr><td colspan="2">Pipework to have a design life of 100 years and designed to HN-HO-72 loadings
Manholes to be located outside of trafficked lane where practicable
Typical minimum pipe cover 900mm in non trafficked areas and 1200mm under pavements
HS2 is the maximum bedding support to be assumed (unless flowable fill is used)
Pipe Class selection to have minimum of 10% reserve capacity strength
Typically minimum pipe angle to road to be 45 degrees</td></tr>
<tr><td>Sub soil drains
(Road drainage)</td><td colspan="2">Physical parameters:
Located 1m below base course, preferably discharging to manholes (or to catchpits if no manhole locally available)
Sub soil pipe surrounded by 20mm to 40mm crushed rock or pea gravel surround
Geotextile rap around gravel, to stop fines from surrounding ground migrating in to drainage material</td></tr>
</table>

[54] i.e. the “dead storage” below the level of the catchpit outlet pipe, which is available for sediment storage.
[55] i.e. the beam that supports the kerb so that water can enter via the back of the catchpit.

<table>
<tr><th></th><th>New KCDC local roads</th><th>New NZTA Expressway</th></tr>
<tr><td rowspan="2">Swales
(Road drainage and Treatment)</td><td colspan="2">Hydraulic parameters:
• Q_2 storm flow level to be below base course level
• Swales to contain the Q_{10} storm event flows
• Swales to contain the Q_{100} storm event flows where no secondary overflow path exists
• Stormwater runoff to be treated in the swale
• Climate change to be applied to all flows
Physical parameters:
• Base and side slopes of swales to be planted – see ULDF for details of plant species (eg Oioi, Wiwi)
• Side slopes to be a maximum slope of 1 vertical to 2 horizontal (typically 1 vertical to 3 horizontal) assuming side slopes are planted
Specific provision in maintenance contracts needs to be made for weeding etc particularly over the first three to five years. Consideration should be given to extending the defects liability period for cover the initial plant establishment for two to three years.</td></tr>
<tr><td>• Local road pavement construction is assumed to have a feathered edge and base course thickness of 500mm
• Swale base is assumed to be 1.5m wide</td><td>• Expressway pavement construction is assumed to have a feathered edge and base course thickness of 700mm
• Swale base is assumed to be 2m wide</td></tr>
<tr><td>Swale underdrains
(Road drainage and Treatment)</td><td colspan="2">Physical parameters:
• Swale underdrains to be provided where longitudinal grade of the swale is less than 2%
• Swale underdrains to fulfil function of (and replace) sub soil drains (where needed), in which case they will need to be 1m below base course level
• Access chamber every 100m required for inspection and maintenance of swale underdrains</td></tr>
<tr><td>Dry ponds
(Attenuation)</td><td colspan="2">Hydraulic parameters:
• Dry pond provides attenuation to post-road construction Q_2, Q_{10} and Q_{100} flows to pre road construction levels
• Climate change allowance incorporated in to pond sizing
Assumption:
• Dry ponds are preceded by a swale (which provides stormwater treatment)
• Dry ponds to blend in with surrounding land use (typically grassed)</td></tr>
<tr><td>Attenuation swales
(Road drainage, treatment and attenuation)</td><td colspan="2">Hydraulic parameters:
• Swales to contain the Q_{100} attenuation volume with 300mm of freeboard to the road edge line
• Climate change included in attenuation volumes
Physical parameters:
• Base and side slopes of swales to be planted – see ULDF for details of plant species (eg Oioi, Wiwi)
• Side slopes to be a maximum slope of 1 vertical to 2 horizontal (typically 1 vertical to 3 horizontal) assuming side slopes are planted
• Bund spacing assumed to be 50 to 100m
• Base width assumed to be 4m wide
• Swale initially sized to hold full Q_{100} (including climate change) runoff (due to limited hydraulic controls)
• Under drain also assumed to be needed
• Hydraulic controls to be provided by a single pipe sized to discharge the ED volume over 24 hours (the Q_{100} volume may therefore take up to 7 days to drain away)
Specific provision in maintenance contracts needs to be made for weeding etc., particularly over the first three to five years. Consideration should be given to extending the defects liability period for cover the initial plant establishment for two to three years. Also provision needs to be made for regular inspections of hydraulic controls within the attenuation swales.</td></tr>
</table>

<table>
<tr><th></th><th>New KCDC local roads</th><th>New NZTA Expressway</th></tr>
<tr><td rowspan="2">Culverts (Minor Waterway crossings[56])</td><td>Culverts will typically take the form of a single cell culvert with headwalls
Hydraulic parameters:
• Culverts to convey the Q_{10} storm flows without heading up more than 2m above the culvert soffit or within 0.3m of the white edge line
• Culverts to convey Q_{100} storm flows where the secondary overflow path would flow through buildings</td><td>Culverts will typically take the form of a single or multiple cell culverts with headwalls
Hydraulic parameters:
• Culverts to convey Q_{100} storm flows without heading up more than 2m above the culvert soffit or within 0.5m of the white edge line
• Culverts to convey the Q_{10} storm flows without heading up above the culvert soffit</td></tr>
<tr><td colspan="2">• Climate change to be applied to all flows
• Back water effects to be kept within the designation where practicable.
• Exceptions to hydraulic sizing are culverts that provide intentional throttling and flood protection to downstream properties (Mangapouri and Racecourse)
Physical parameters:
• The culvert design life will be 100 years and designed to HN-HO-72 loadings and NZTA F3: 2010
• Fish passage is expected to include a combination of: depressed culvert inverts, fish ramps, continuation of stream substrate through culverts and artificial features to provide resistance and variation to the flow
• Erosion protection to be provided both upstream and downstream of culverts
• Where practicable, culvert orientation will be perpendicular to the centre line of the road, and constructed off line (of the existing waterway)</td></tr>
</table>

Existing Road Surfaces

Where existing SH1 is converted to a local road, we intend that there should be no worsening of the existing runoff quality or peak flows. We propose that this is achievable by not modifying the existing situation. In some cases, the paved surface is expected to reduce, as the road is converted from four lane State Highway to a two lane local road.

Where local road is modified but remains a local road, we also propose to leave the existing situation as it is.

Where existing SH1 is modified and becomes the new Expressway, we intend that there should be no worsening of the existing situation. In general this will be achievable by treating and attenuating the equivalent increase in road area only, however we will evaluate opportunities to retrofit existing pavement areas on a case-by-case basis. For road drainage and minor waterway crossings we propose the existing situation needs to be upgraded to provide safe passage of emergency vehicles in a flood event.

New Sections of Rail

Design parameters for new sections of rail are detailed in the KiwiRail Basis of Design report. These are based on the design parameter summarised in Appendix 3, (which are

[56] Minor waterway crossings refer to all waterway crossings with the exception of the four major crossings (Ōtaki, Waitohu, Mangaone, Mangapouri). For information on the major crossings refer to the hydraulics and modelling report.

from the 2008 WRRP MacKay's to Waikanae Double Tracking project). We note that the final extent of the rail track foot print will be similar to present.

6.5 General design approach

The stormwater design and assessment for this Project has several principal components as shown in Table 9 below.

Table 9: Stormwater Design and Assessment Components

Component	Design and assessment steps
Major waterway crossings (bridges and major areas of flooding)	See Technical Report Nº 9.
Waterway crossings (culverts)	• assessment of waterway flows • assessment of the existing hydraulic situation • design of culvert sizes • assessment of upstream and downstream effects (particularly head water pond changes) and • assessment of the extreme (i.e. super-design) event.
Road runoff treatment	• assessment of runoff volumes • design of treatment devices • assessment of treatment devices against design criteria.
Road runoff attenuation	• assessment of road runoff flows • design of collection and conveyance systems • design of attenuation devices • assessment of attenuation devices against the design criteria

6.5.1 Waterway Crossings (Culverts)

The Q_{100} flood flows for the small to medium sized streams were sized using the U.S. Department of Natural Resources Soil Conservation Service (SCS) method, used in accordance with KCDC's Subdivision requirements.

The method assesses characteristics of the catchments in question and then applies a nested storm distribution to the catchment. We have modelled this using HEC HMS software[57] and the inputs and outputs can be found in Appendix 1.

The Q_{100} flood flows were also compared with results derived from use of the regional flood estimation method (based on the Mangaone stream flow data).

Once we had established the flow for a stream, we assessed the hydraulics of the existing situation. As the Expressway is adjacent to (or replacing) the existing SH1, the hydraulics of the existing culverts became ether a tailwater or headwater constraint. We assessed the

[57] Developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center

existing situation by modelling the existing culverts (size, road level, inverts, downstream water levels) using HY-8 software.

We then used the *existing situation* results as constraints in the *future situation* culvert model. For example, the headwater depth derived from our analysis of the NIMT railway culverts became the tailwater in our design of the Expressway culvert immediately upstream. By doing this we were able to show that there are no upstream or downstream effects (or alternatively assess what those effects are).

Finally we applied an extreme (i.e. super-design) event flows[58] to the proposed model to assess whether the road overtops and determine where the secondary overflow path would be.

Culvert calculations (including assessment of physical inputs, diagrammatic long-sections, and HY-8 outputs) can be found in Appendix 4. An allowance for fish passage has been allowed for in the sizing of the culvert by embedding the culvert invert below stream bed level and increasing the roughness of the culvert base (example fish passage details are included in Appendix 5).

6.5.2 Road runoff treatment

It is not generally practicable to eliminate all road-derived contaminants from stormwater discharges; therefore a best practicable option (BPO) approach is normally adopted. The BPO is defined by NZTA's Stormwater Treatment Standard for State Highway Infrastructure. We assessed the water quality volumes (upon which devices are designed and sized) using the NZTA rainfall charts. The water quality volume is defined by the 90th percentile storm, ie the storm for which 90% of all rainfall events will be smaller.

We then chose appropriate treatment devices along the route (generally swales) and iteratively designed them to meet the NZTA criteria (such as average residence time, maximum flow velocity and maximum depth). Provided that the treatment device is designed and maintained according to the NZTA standard, the expectation is that there will be at least 70% removal of suspended solids (together with a proportion of other pollutants bound to them) on a long term average basis.

As the majority of the swales have attenuation bunds built into them, the water will be in the swale for longer than the minimum required and thus the percentage removal is likely to be even higher.

6.5.3 Road runoff attenuation

We have taken a robust approach to the design of the attenuation swales. We first assessed the Q_{100} 24 hour rainfall depth (including climate change) from the KCDC rainfall maps, converted this depth into a volume, and sized our attenuation swales to be able to hold 100% of this volume.

[58] The extreme flood event being defined by GWRC as: 1.5 times the Q_{100} flow plus climate change to 2090.

The reason for this is it allows very simple hydraulic controls at each intermediate bund within the swale. This reduces expensive pipework (such as carrier pipes or complex hydraulic structures) and also reduces the time to construct each bund.

The attenuation swales then drain down through orifices sized to drain the water quality volume over 24 hours. This will provide greater attenuation than required.

The design for the attenuation basin is proposed to be more conventional, attenuating peak flows to their pre existing levels.

6.6 Waterway crossing constraints

This section describes the constraints and considerations for the small to medium waterway crossings (the Ōtaki River, the Waitohu Stream, the Mangaone Stream and the Mangapouri Stream are covered in Technical Report N° 9).

6.6.1 Greenwood Culvert

The Greenwood Catchment becomes a sub-catchment of the Waitohu Stream in flood events. As such the sizing and assessment of the culvert and its effects has been done as part of the Waitohu Stream flooding assessment (Technical Report No 9). See Figure 7.

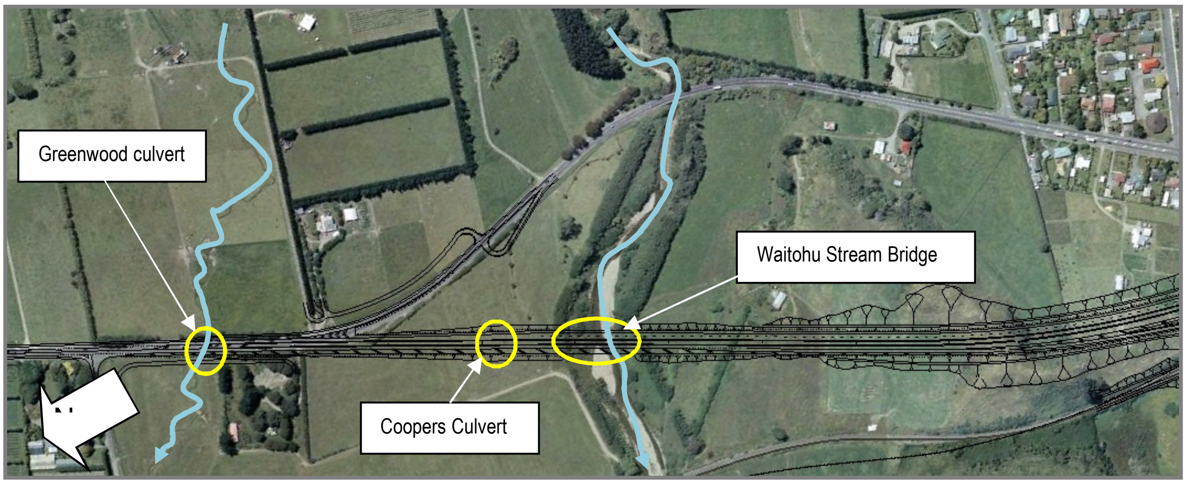

Figure 7: Greenwood, Coopers and Waitohu Stream crossings

6.6.2 Coopers Culvert

This culvert is a dry culvert. It provides additional capacity for carrying the Waitohu flood waters beneath the Expressway. See Figure 7.

6.6.3 Waitohu Bridge

The Waitohu Catchment has been the subject of a specific hydraulic assessment. As such the sizing and assessment of the bridge and flood plain is detailed in Technical Report No 9[59]. See Figure 7.

6.6.4 Waitohu Tributary Culvert

This culvert conveys a tributary of the Waitohu Stream. In large events it becomes inundated by and incorporated into the wider Waitohu Stream flood plain.

6.6.5 Te Manuao, Railway Wetland Outlet, and Kennedy Wetland Outlet Culverts

The Te Manuao Catchment has a reticulated system with a 450mm diameter pipe under the existing SH1. In large storm events there will be significant overland flow as the pipe system has limited capacity.

The alignment of the existing road will be adjusted slightly at the point the 450mm diameter pipe crosses SH1, necessitating a pipe extension at the same size.

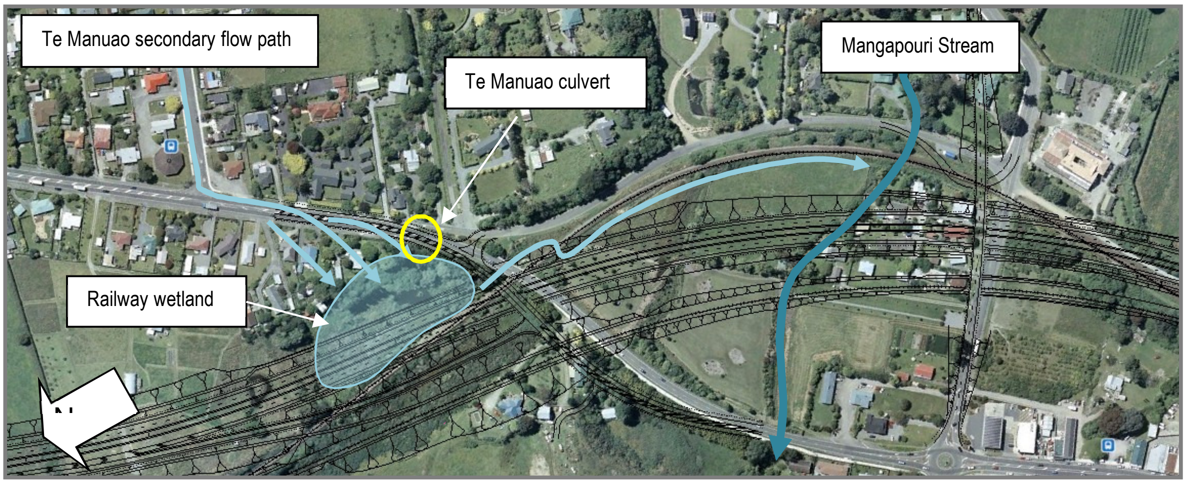

Figure 8: Te Manuao flow path

The flood waters will continue to follow the same overland flow paths as they do now (down Te Manuao Road and over SH1). The flow from this catchment does not pass directly under the Expressway; instead it flows into and out of the railway wetland and discharges (via an open drain and two further culverts, the Railway Wetland Outlet Culvert and the Kennedy Wetland Outlet Culvert) to the Mangapouri Stream (see Figure 8). Only then does this water pass under the Expressway. The Te Manuao catchment has therefore been integrated into the Mangapouri Stream model.

The existing Railway Wetland will be reduced in size due to the Expressway alignment. The hydraulic effect of this is detailed in Technical Report No 9.

[59] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, 2012

6.6.6 Mangapouri Culvert

The existing Mangapouri culvert acts as a throttle and is considered to provide downstream flood protection. The Mangapouri Catchment has been the subject of a specific hydraulic study. As such the sizing and assessment of the flood system is detailed in Technical Report No 9 report[60].

6.6.7 Rahui Rd Culverts

The Mangapouri hydraulic study identified an additional flow path that will convey break-out flow from the Managapouri Stream towards the Racecourse channel during large events. Refer to Technical Report No 9 for further details. Two new culverts will be installed under the Rahui Rd overbridge and the existing Rahui Rd to convey this flow.

6.6.8 Racecourse Culvert

The Racecourse catchment (despite what the name suggests) does not include the Ōtaki Racecourse. The stream ends about 400m downstream of the Expressway in a formalized soakage area. The existing culvert under the railway is a 1.2m by 1.2m box and can convey the Q_{100} flow from this catchment with no heading up. However, during flood conditions some of the water from the Mangapouri Stream overflows into this catchment. It is under these conditions that the existing culvert acts as a throttle.

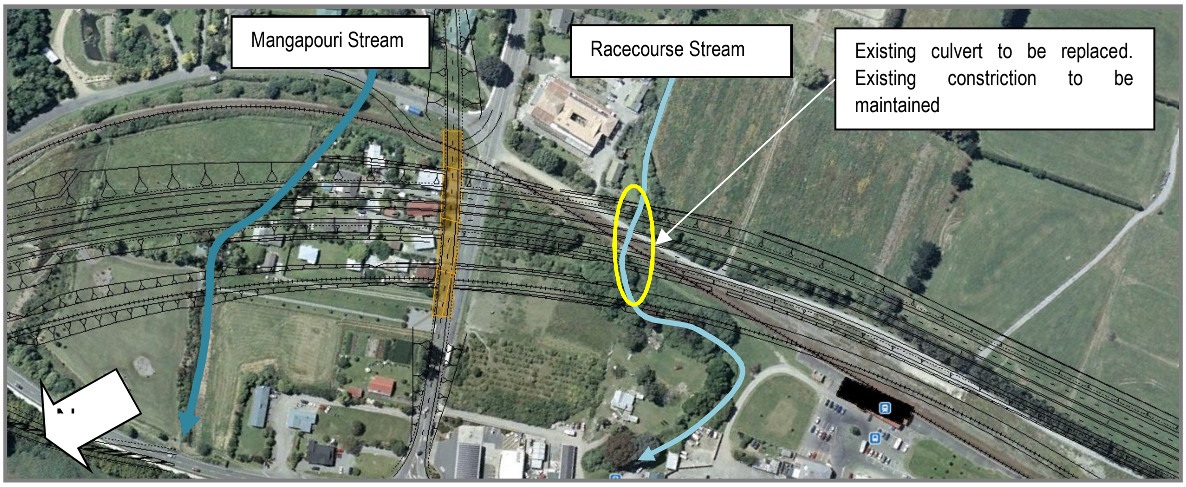

Figure 9: Racecourse Stream

The Expressway will be built over the location of this existing culvert, so the existing culvert will need to be replaced. We propose to replace the existing culvert with a new culvert that has the same capacity, and provides the same degree of throttling of flood flows.

[60] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, 2012

6.6.9 Te Roto Culvert

The Te Roto Stream appears to end in a soakage bowl just upstream of the railway. This soakage bowl was also dry. The plants within the stream bed were the same as the plants on the surrounding ground.

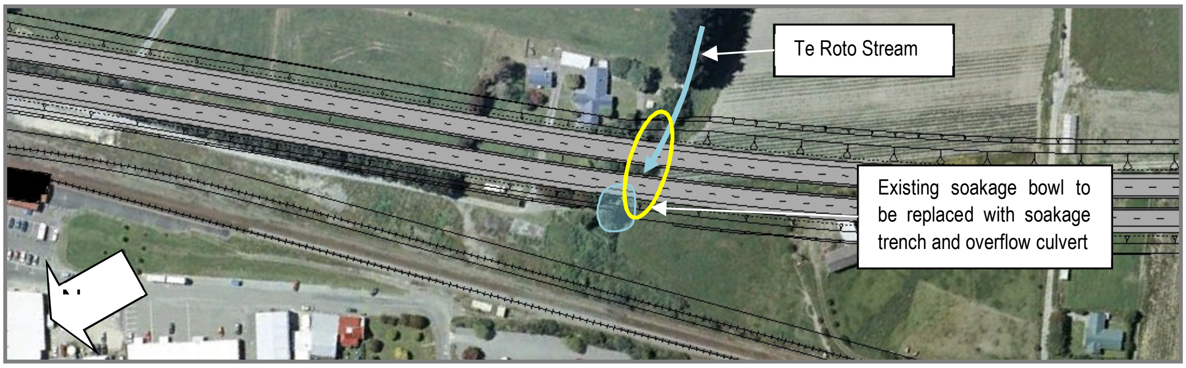

Figure 10: Te Roto Stream

The Expressway alignment will eliminate this soakage bowl, so we have opted to replicate the situation as far as practicable with a new soakage trench on the upstream side of the Expressway, sized to soak away the Q_{100} storm (assuming an infiltration rate of 1mm per minute which has been estimated from geotechnical investigations). We are also proposing a nominally sized culvert under the Expressway to replicate the ability of the existing soakage bowl to overflow. The adjacent dwelling is due for removal, and will not therefore be affected by relocation of the soakage device.

6.6.10 Andrews Culvert

The Andrews catchment has no defined channel. In the existing situation water will run off the adjacent land and collect along the railway embankment. The ground in this area is made up of a topsoil layer underlain by tens of metres of river gravels. The river gravels provide very good soakage for any water that collects in this area.

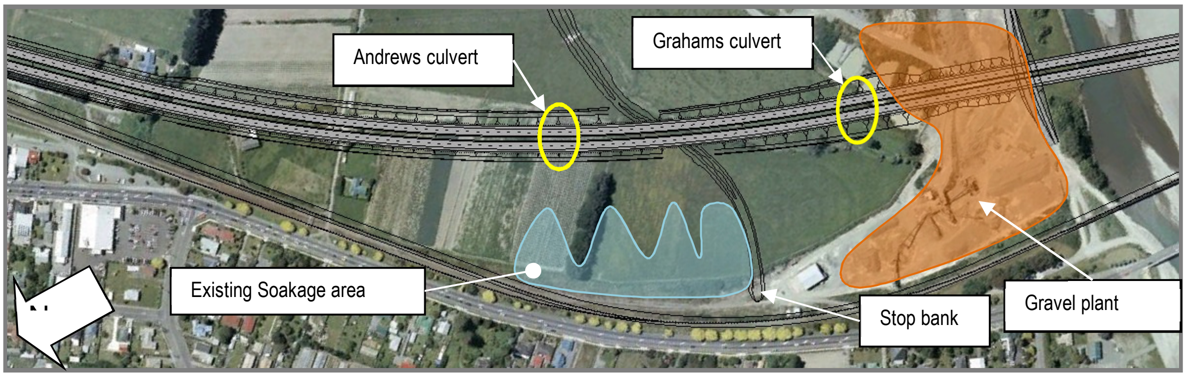

Figure 11: Andrews Culvert

To replicate the existing situation as far as practicable, a large culvert has been placed under the Expressway so excess water can still be routed to the existing soakage area. This culvert will only convey significant flow if the primary Ōtaki River stopbank overtops or fails. Refer to Technical Report No 9 for further details.

6.6.11 Grahams Culvert

The Grahams catchment has no defined channel. In the existing situation water will run off the adjacent land and ether collect to the west of the gravel plant (see Figure 11) or drain through the gravel plant to the Ōtaki River. The ground in this area is made up of a topsoil layer underlain by tens of metres of river gravels. The river gravels provide very good soakage for any water that collects in this area.

To replicate the existing situation as far as practicable, a nominally sized culvert has been placed under the road so excess water can still be routed to the existing soakage area.

At this stage the future configuration of the existing gravel extraction plant is yet to be decided, so it may be possible to discharge stormwater directly to the Ōtaki River rather than to soakage.

6.6.12 Ōtaki River Bridge

A new bridge over the Ōtaki River is proposed. The Ōtaki River Catchment has been the subject of a specific hydraulic study. As such the sizing and assessment of the bridge and flood system is detailed in Technical Report No 9 [61]. See Figure 12.

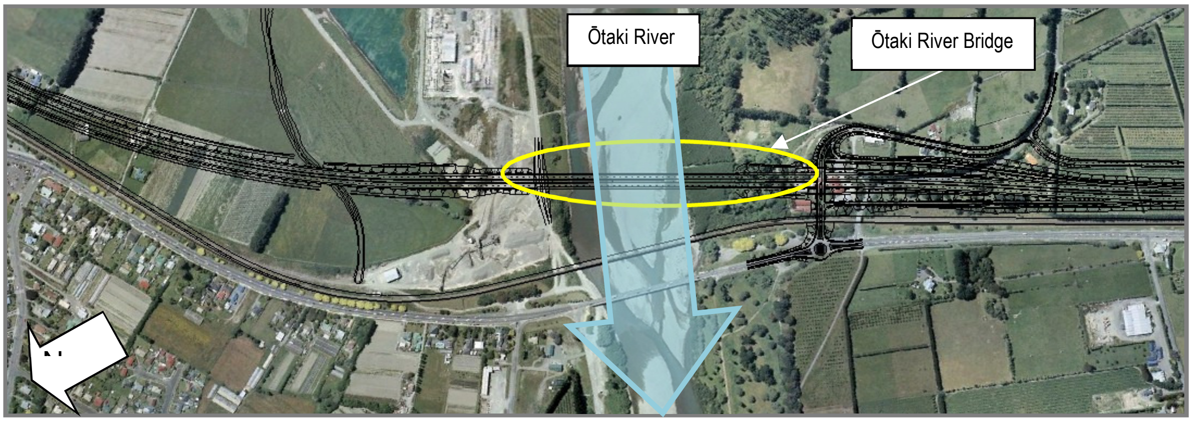

Figure 12: Ōtaki River crossings

6.6.13 Mangaone Culverts and Bridges, including Lucinski Overflow Culvert

The Mangaone catchment has a complicated flood plain that is influenced by the existing rail and SH1 embankments. This has been the subject of a specific hydraulic study. As such the sizing and assessment of the culverts' flood system is detailed in the Technical Report No 9. See Figure 13.

[61] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012

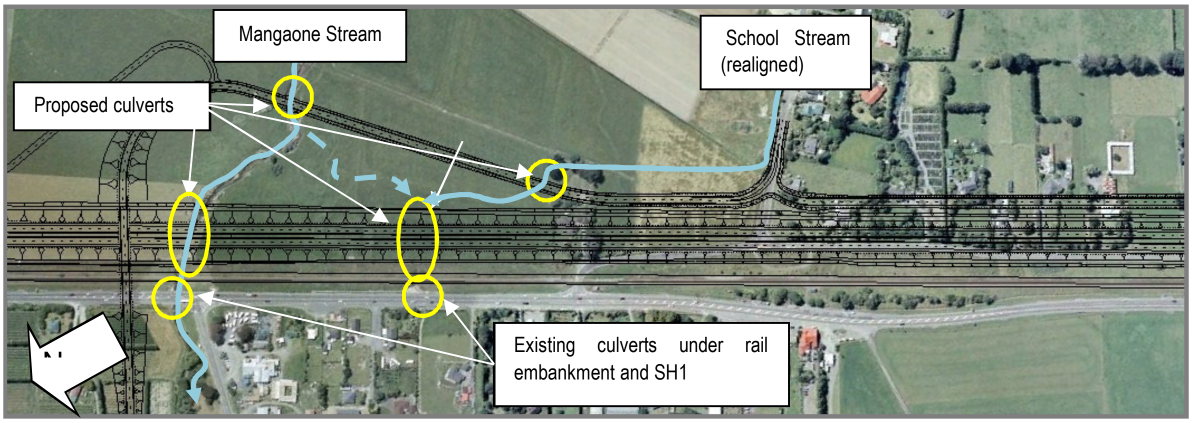

Figure 13: Mangaone and School crossings

6.6.14 School Culvert

The School Catchment becomes part of the Mangaone Catchment in flood events. As such the sizing and assessment of the culvert and effects has been considered as part of the Mangaone Stream flooding assessment and detailed Technical Report No 9. See Figure 13.

6.6.15 Gear Culverts and Settlement Heights Culvert

The Gear and Settlement Heights streams are within 300m of each other. Whilst this is not deemed to be close enough to combine the culverts, they do share a common flood pond in large events. The flood area is currently a factor of the culvert constraints along the rail embankment and the existing flood levels are a significant constraint on the design of the proposed culverts. Gear Road is proposed to be moved and a new culvert will be required. Also the alignment of the Gear Stream will need to be altered.

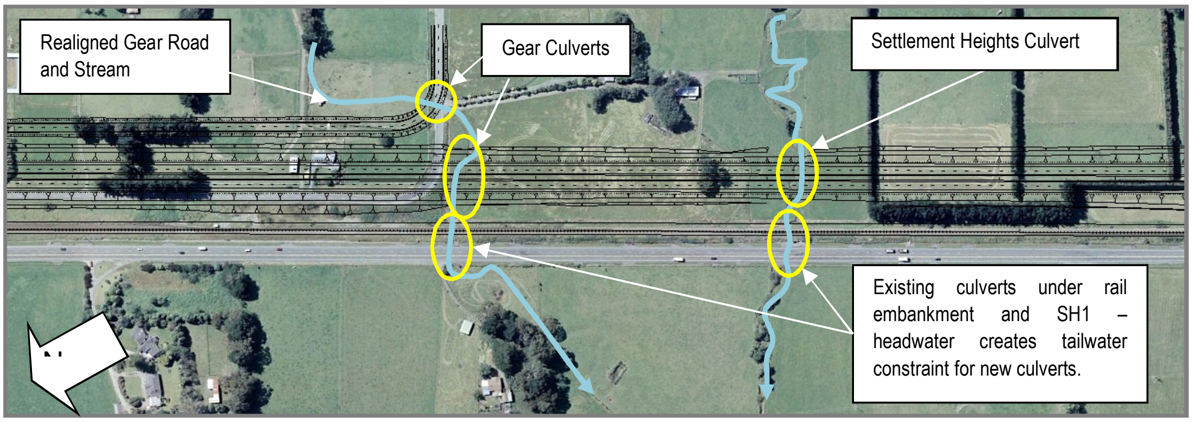

Figure 14: Gear and Settlement Heights Culverts

6.6.16 Coolen and Avatar Culverts

The Coolen and Avatar Catchments have no defined stream channel and the location of the existing culverts (under the rail embankment and SH1) are not at a low point in the topography. Any water that bypasses these culverts will drain down the Settlement Heights culvert.

6.6.17 Edwin Culvert

The Edwin Catchment is nominally sized to reflect adjacent state highway and railway culverts (it is also allowed for as part of the Jewell Catchment). The culvert provides flow to a short downstream channel reach, and could also provide a water source for a proposed ecological enhancement wetland.

6.6.18 Jewell Culvert

The proposed Jewell Culvert is located directly downstream of the existing culverts under the rail embankment and SH1. The flow through the existing culverts is affected by the immediate downstream conditions. The proposed culvert needs to have sufficient capacity so as to not affect the flow through the existing upstream culverts (which in turn affects the upstream flood level).

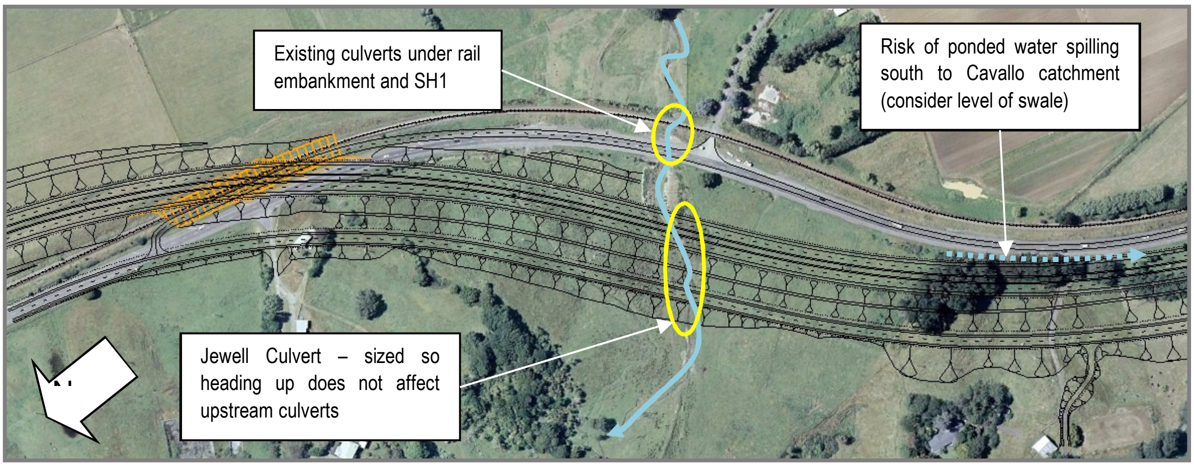

Figure 15: Jewell Culvert

6.6.19 Cavallo and Cording Culverts

The Cavallo and Cording Catchments have no defined channel. There are multiple existing small culverts under the rail embankment and SH1 in this area. The new Cavallo culvert is positioned and sized to receive all flow from the Cavallo and Cording Catchments. The Cording Culvert may not be needed, however, if it is, it will only be an extension of an existing 450mm diameter pipe under the existing SH1.

6.6.20 Awatea and Kumototo Culverts

The Awatea and Kumototo culverts both replace existing culverts (twin 900mm diameter and 1350mm diameter respectively under SH1. In both cases the proposed culverts are being made larger than the existing culverts. The constraint on the design of these culverts was to ensure that there was no significant increase in the water released downstream in a flood event.

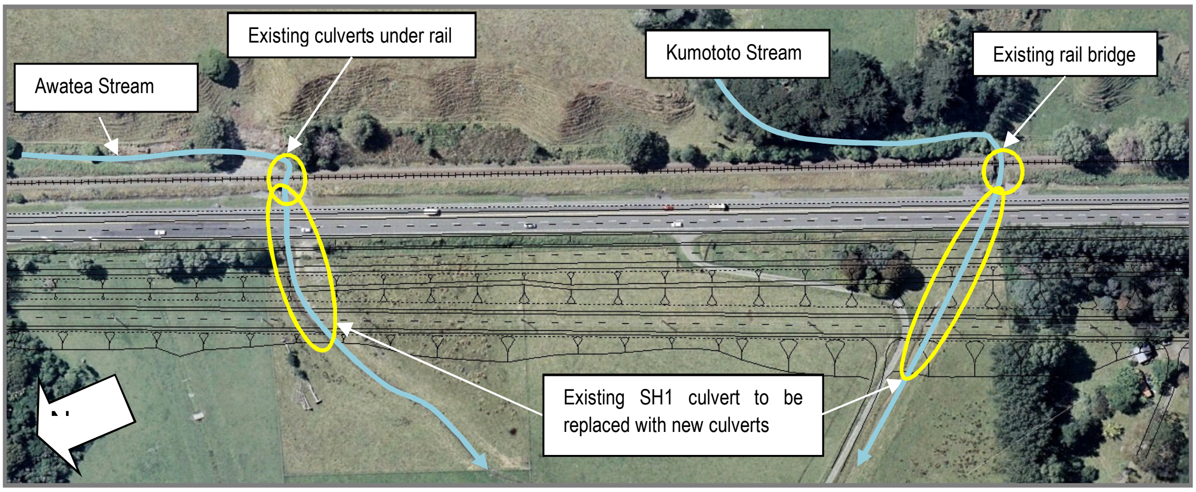

Figure 16: Awatea and Kumototo Culverts

6.7 Road runoff attenuation and treatment proposal and constraints

This section describes the road runoff management, which includes collection, conveyance treatment and attenuation of the rain that falls and runs off the Expressway.

Table 10 details the road runoff attenuation and treatment for the Expressway, with the following sections giving more detail in certain areas.

Table 10: Road runoff management by chainage

Chainage (m)	Road runoff management[62]	Discharge point[63]
0 to 280	As existing (no change)	North to existing drainage
280 to 400	Attenuation swales	Greenwood Stream
400 to 550	Attenuation swales	Greenwood Stream
550 to 1000	Attenuation swales	Waitohu Stream
1000 to 2100	Treatment swales followed by attenuation basins	Mangapouri Stream
2100 to 2600	Attenuation swales	Racecourse Stream
2600 to 3100	Treatment swales	Soakage area
3100 to 4100 (Ōtaki River Bridge)	Kerb and channel with pipework, followed by treatment swales	Ōtaki River
4100 to 5200	Treatment swales	Ōtaki River
5200 to 7500	Attenuation swales	Mangaone Stream
7500 to 8600	Attenuation swales	Gear Stream
8600 to 9050	Attenuation swales	Settlement Heights Stream
9050 to 9400	Attenuation swales	Coolen Culvert
9400 to 9700	Attenuation swales	Avatar Culvert
9700 to 10200	Treatment swales followed by attenuation area	Jewell Stream

[62] Attenuation swales provide attenuation and treatment; treatment swales provide treatment but not attenuation.

[63] Attenuation of road runoff is not provided where the discharge point is either the Ōtaki River or to soakage.

Chainage (m)	Road runoff management[62]	Discharge point[63]
10200 to 10400	Attenuation swales	Jewell Stream
10400 to 11150	Attenuation swales	Cavallo Stream
11150 to 11550	Attenuation swales	Awatea Stream
11550 to 11700	Attenuation swales	Kumototo Stream
11700 to 12250	Attenuation swales	South to M2PP drainage

The majority of the Project is through a rural landscape where we have been able to provide swales that serve as collection, conveyance, treatment and attenuation devices (with the attenuation provided through the use of internal bunds).

There are three significant locations where the road runoff management differs from this approach. These are described in more detail below.

6.7.1 Chainage 1000 to 2100 (Railway/Kennedy Wetlands and Taylor Basin)

The Expressway cuts through existing sand dunes and an existing wetland with constrained geometrics in this location. The result is that there is not enough width to have attenuation swales. Instead we have proposed normal treatment swales (providing collection, conveyance and treatment) with the attenuation provided in two separate areas. Figure 17 shows the catchment areas draining to the different attenuation areas.

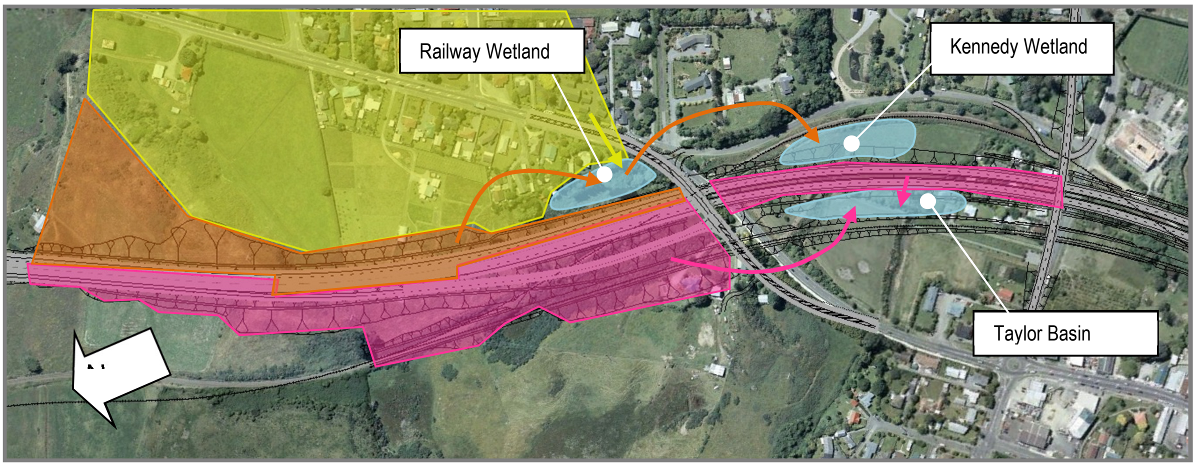

Figure 17: Runoff areas to Railway Wetland and Taylor Basin

The first area is called the Taylor Basin, and is located between the Expressway and the relocated railway. This area is generously sized so it can easily store all the water that drains to it and release it slowly to provide a high level of attenuation.

The second area is a combination of the remaining Railway Wetland and a new proposed wetland called the Kennedy Wetland. This area is complicated. There are three sources of water to be considered: the water draining from the road, the water that has always drained into the Railway Wetland and the Mangapouri Stream. This system has been modelled (see the Hydraulic report[64]) to show that existing flooding is not made worse by the Project.

6.7.2 Chainage 3200 to 4000 (the Ōtaki River Bridge)

We propose that the rain that falls on the proposed Ōtaki River Bridge will be collected by kerb and channel, and conveyed by pipes to approximately 300 m past the northern bank of the river. This will allow the runoff to be treated as it goes through the swales before discharging to the river.

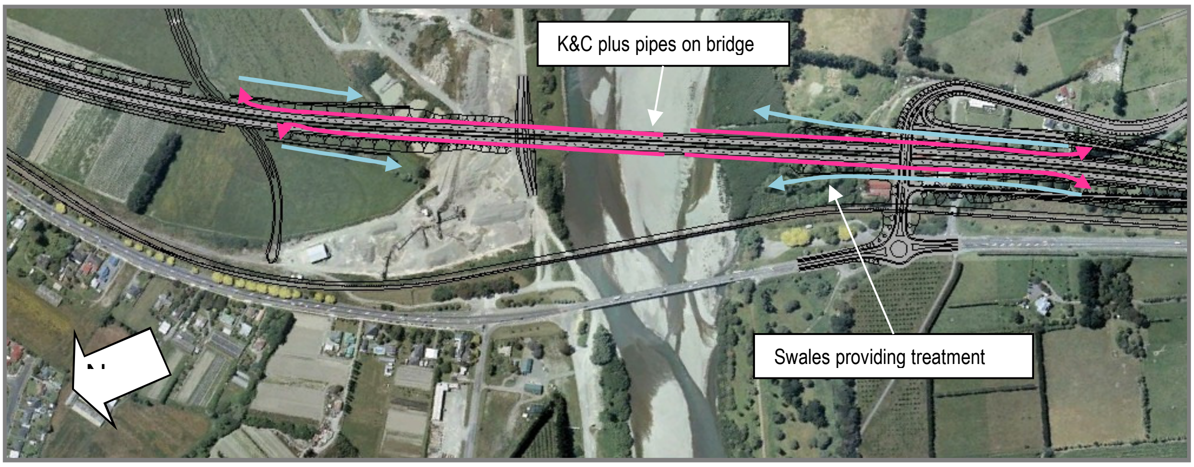

Figure 18: Runoff from Ōtaki River Bridge

The pipes discharge road runoff to swales. The swales provide treatment to the road runoff and carry the water back to the Ōtaki River. No peak flow attenuation is required.

6.7.3 Chainage 9700 to 10200 (Valentine Basin at Mary Crest)

Around the Mary Crest area, the Expressway threads between the existing SH1 and some native bush (which has ecological significance).

[64] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012

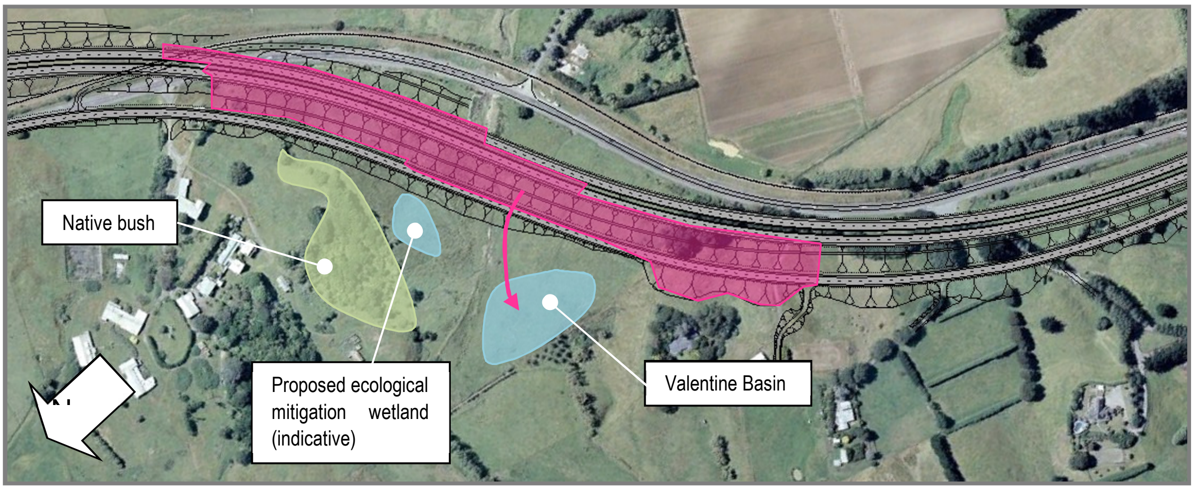

Figure 19: Runoff to Valentine Basin

Again the footprint of the proposed roads has been narrowed so there is not enough space for attenuation swales. Instead runoff from the road will drain to, and be attenuated at, Valentine Basin. Figure 19 shows the area draining to Valentine Basin and the location of the native bush. A further wetland is proposed in the vicinity to partially offset the ecological effects of wetland losses elsewhere on the Project. This ecological wetland does not provide a stormwater function, and is not considered further in this report.

7 Effects Assessment and Mitigation Design

This section describes how the stormwater aspects of the Project (which are all forms of mitigation) have been designed to reduce or eliminate the stormwater effects identified in Section 5. It also describes any residual effect that was unable to be designed out. Residual effects are summarised in the next chapter.

7.1 Construction-Related Effects

A Draft Erosion and Sediment Control Plan[65] has been compiled in accordance with Greater Wellington Regional Council and the New Zealand Transport Agency guidelines and will remain a live document to meet the evolving demands during construction.

The GWRC and NZTA Guidelines for erosion and sediment control adopt a best practicable option (BPO) approach with regards to installation and monitoring of E&SC practices, where best management practices are applied to minimise sediment yields. With a BPO approach, providing that the design and operation of E&SC's are carried out in accordance with the best practice guidelines, this provides the basis for confirming compliance with consent conditions.

The soil composition throughout the Project length is predominantly composed of sands and gravels and so soil particle sizes are generally large and heavy when compared to that of silt and clay soils. On this basis retention practices such as decanting earth bunds and sediment retention ponds are expected to perform well.

The estimated sediment yield within each catchment due to construction activity (calculated via USLE[66]) was compared to the sediment yield from the entire catchment estimated using the Water Resources Explorer New Zealand (WRENZ) model. This comparison should be interpreted with extreme care, as it involves comparison of results from two quite different, approximate, empirically-based assessment techniques; however the differences in yield are so marked (with the exception of the focus areas discussed separately below) that a compelling argument can still be made that sediment yield resulting from construction will be tiny compared to the natural base sediment flow in the major watercourses.

When the increase in sediment due to construction is assessed against that of the whole catchment, the percentage increase for the three waterways of significance is in the order of:

- 0.2% for the Waitohu catchment;
- 0.003% for the Ōtaki River catchment;
- 0.1% for the Mangaone catchment.

[65] *Peka Peka to North Otaki Expressway Project Draft Erosion and Sediment Control Plan*, in Appendix C of the Contractor's Environmental Management Plan (refer Project AEE, Vol 4) (Opus, Nov 2012)
[66] Universal Soil Loss Equation, U S Soil Conservation Service

Based on these findings and providing best practice is followed, the short term effects of land disturbance due to construction on the three waterways of significance is expected to be minor.

The USLE evaluation presented in the ESCP does however identify catchments that are much more sensitive to the effects of construction. In such locations particular attention will be required to limit sediment reaching the watercourses. The areas sensitive to the effects of construction are summarised below:

- Te Manuao: Estimated 46% above baseline
- Andrews 1: Estimated 22% above baseline
- Andrews 2: Estimated 37% above baseline
- Cavallo: Estimated 80% above baseline

There are three main cuts on the project and the Te Manuao and Cavallo catchments are both sensitive to construction because they each contain one of these large cuts. The Andrews catchments are sensitive to the effects of construction because the upstream catchment is very small and the disturbed areas account for 73% of the total catchment.

The Cavallo catchment in the Mary Crest area has been identified as being the most sensitive area to the effects of construction. For this reason a Site Specific Environmental Management Plan (SSEMP) has been developed for this particular site. Another SSEMP has been developed for the central Ōtaki area, including the railway wetland and the Pare-o-Matangi Reserve.

The SSEMP documents demonstrate the application of the methodologies and principles outlined in the E&SCP, and provide confidence that the works can be constructed to ensure that environmental matters are appropriately managed.

Chemical treatment will deliver little additional benefit, given the predominantly sand/gravel soils, and is not expected to be widely utilised.

7.2 Waterway crossings

Each small to medium waterway crossings is discussed in the following sections, with the larger waterway crossings covered in Technical Report No. 9.[67]

7.2.1 Culvert Schedule

Table 11 provides a summary of proposed culverts, also noting whether an allowance for fish passage is to be made. A more detailed culvert schedule (with comments) is given at the end of Appendix 4, which also includes design flows, culvert grade and design comments. Waterway crossings are ordered form north to south and are labelled on the stormwater drawings located in Appendix 5.

[67] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydrhyaulic Effects for Major Watercourse Crossings*, Opus, 2012

Proposed culvert cross sections are based on the following:

- All flows include allowance for climate change to 2090
- Culverts to convey Q_{10} flows without surcharging above pipe soffit[68] level
- Culverts to convey Q_{100} flows with no more than 2m headwater depth, and headwater pond no closer than 500mm (vertically) from road edge.
- Culvert size increased where necessary to permit partial embedment for fish passage
- Culverts to be assessed to identify anticipated effects of extreme (i.e. super-design: $1.5x(Q_{100} + CC)$) flows.

No specific culvert blockage scenario was tested, however the extreme (super-design) event scenario can be used to provide a preliminary indication of potential effects associated with a proportionate reduction in pipe capacity due to blockage.

In the absence of comprehensive survey data, some culvert invert levels have of necessity been assumed. Greater analytical precision might have been achieved if survey data was available, however since flood extents are generally governed by road and rail overflow levels (which are available) the gaps in culvert survey are not considered critical, and relevant assumptions will be confirmed as detailed design of culverts is finalised.

Table 11: Culvert schedule

Waterway Crossing	Fish passage allowance[69]	Culvert Cross-section (m)[70]	Culvert length (m)	Disturbed waterway length[71] (m)
Greenwood Culvert	Yes	4 x 2 (est.)	25	55
Coopers Culvert	No	3 x 0.450 dia.	40	-
Waitohu Bridge	Yes	~ 75m span	-	-
Waitohu Tributary Culvert	Yes	5 x 1 (est.)	40	60
Te Manuao Culvert	No	0.450 dia.	5 (est.)	10

[68] i.e. inside top of pipe

[69] Technical Report No 12 (Aquatic Ecology) describes fish passage as required where the stream has a defined channel and has a tributary network. This guidance has been applied here.

[70] NZTA traditionally defines waterway crossings with area greater than $2.4m^2$ as a "bridge" even though they remain culverts, both structurally and in terms of hydraulic design. Several of the culverts in this list come into this category. Moreover future design optimisation may prompt a change of structural form from culvert to bridge.

[71] The disturbed waterway length includes the preliminary design length of the culvert and any stream diversion, plus an allowance for headwall apron lengths and riprap. This is an estimate only; headwall and riprap detail will need to be specifically designed at detail stage.

Waterway Crossing	Fish passage allowance[69]	Culvert Cross-section (m)[70]	Culvert length (m)	Disturbed waterway length[71] (m)
Remnant Railway Wetland Outlet Culvert	Yes[72]	1.0 dia.	75	95
Kennedy Wetland Outlet Culvert	Yes[72]	1.0 dia.	15	20
Mangapouri Culvert[73] (Expressway)	Yes	3 x 3	60	100
Mangapouri Culvert (relocated NIMT railway)	Yes	3 x 3	20	60
Rahui Road Overbridge Culvert	No	10 x 2	~ 20	-
Rahui Road flood relief Culvert	No	1.5 x 0.5	115	-
Racecourse Culvert	No	1.5 dia. or 1.35 dia.[74]	100	210
Te Roto Culvert	No	0.525 dia.	40	65
Andrews Culvert/Ōtaki Overflow Culvert	No	40 x 1.5	40	-
Grahams Culvert	No	0.525 dia.	52	56
Ōtaki Bridge	Yes	~ 320m span	-	-
Mangaone link road (east) Culvert	Yes	10 x 2 (est.)	16	35
Mangaone Culvert - Expressway	Yes	5 x 2 (est.)	50	80
Mangaone link road (west) bridge	Yes	Single span bridge	-	-
Lucinsky overflow culvert – link road (west)	No	10 x 1 (est.)	16	-

[72] Fish passage required for eel species only.
[73] Currently the proposed culvert under the Expressway and the relocated NIMT railway are separate culvert however there is scope to combine these together. This would increase the potential size of the Taylor Basin.
[74] Depending on alignment of culvert. If perpendicular to Expressway, the culvert will be shorter and needs to be 1.35m diameter, or it the culvert is at 45 degrees to the Expressway (reducing the length of new stream channel) it will be longer and needs to be 1.5m diameter to provide the same hydraulic throttle as existing.

Waterway Crossing	Fish passage allowance[69]	Culvert Cross-section (m)[70]	Culvert length (m)	Disturbed waterway length[71] (m)
Mangaone Overflow Culvert - local link road (east)	No	Not known	16	-
Mangaone Overflow Culvert – Expressway	No	8 x 1.5 (est.)	50	-
School Rd Culvert – link road (east)	No	Not known	16	520
Gear Road Culvert	Yes	3.5 x 2	20	1 050
Gear Expressway Culvert	Yes	5 x 2	40	90
Settlement Heights Culvert	Yes	10 x 2	40	170
Coolen Culvert	Yes	0.6 dia.	40	44
Avatar Culvert	No	1.2 dia.	60	64
Edwin Culvert	Yes	1.2 dia.	100	200
Jewell Culvert	Yes	Twin 3.5 x2.5	120	140
Cavallo Culvert	Yes	1.5 dia.	80	320
Cording Culvert	No	0.450 dia.	70	75
Awatea Culvert	Yes	Twin 1.8 dia.	68	90
Kumototo Culvert	Yes	Twin 1.5 dia.	88	115

7.2.2 Greenwood Culvert

The general design and assessment of flood effects has been done as part of the Waitohu Catchment flood assessment.

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR11 included in Appendix 5. This includes embedding the invert, creation of a low flow channel, increased roughness of the low flow channel (ie angular rock substrate not smooth concrete), boulder rows to locally slow flow and create variation. A particularly important detail to note is that the downstream invert is at or below the level at which water ponds in the downstream riprap.

7.2.3 Coopers Culvert

As described in section 6.6.2, this culvert is needed to convey the Waitohu flood waters. As such the effects are considered in Technical Report No 9.

7.2.4 Waitohu Bridge

The Waitohu Catchment has been the subject of a specific hydraulic study. As such the sizing and assessment of the bridge and flood plain is detailed in Technical Report No 9[75].

7.2.5 Te Manuao Culvert

As described in section 6.6.4, the Te Manuao culvert is a minor pipe extension. The effect of increasing the last pipe in a reticulation system is negligible. Fish passage is not required from the Railway Wetland into the reticulation system.

7.2.6 Mangapouri Culvert

The Mangapouri Catchment has been the subject of a specific hydraulic study. As such the sizing and assessment of the flood system is detailed in Technical Report No 9[75].

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR10 included in Appendix 5. This includes embedding the invert, the creation of resting pools within the culvert between rock ramps and by ensuring that the downstream culvert invert is at or below the level at which water ponds in the downstream riprap.

7.2.7 Racecourse Culvert

As described in section 6.6.8, the existing Racecourse Culvert will be replaced with a new culvert of the same hydraulic capacity. So there will be no change to upstream or downstream flood conditions.

In large storm events, flood water from the Mangapouri Catchment spills into this catchment. This is assessed as part of the Mangapouri model and detailed in Technical Report No 9[75].

This stream has no tributary network so fish passage is not required; this is in line with the recommendations given in Technical Report No 12 (Aquatic Ecology).

7.2.8 Te Roto Culvert

As described in section 6.6.9, the Te Roto Stream is dry most of the time. The stream ends in a soakage area which has the capability to overflow in large storm events. In order to have no effect, the soakage area has been replaced with a new proposed soakage area, just upstream and a culvert under the Expressway to allow overflows to continue in large events.

The proposed soakage area is designed to store and soak away the Q_{100} storm event and has a similar storage volume to the existing soakage area (which is nominally 1m deep, and 5 to 6m round in plan).

[75] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012

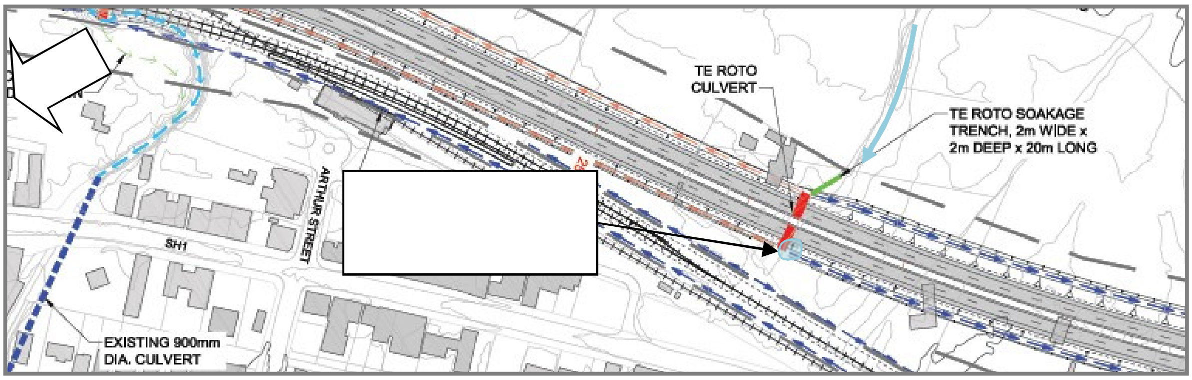

Figure 20: Te Roto soakage area

Given that the existing and proposed soakage areas are within 50m of each other and have a similar volume of storage, the effect on the ground water level will be minimal. The exact frequency of overflow may be reduced slightly however this is only manifest in large storm events and the effect this will have on the environment is negligible.

Ongoing (from March 2011 to September 2012) ground water monitoring in this area (BH 105 and 107) show fluctuations between 2.9m and 3.3mbgl (taking a ground level of 13.5m). We recommend that any excavations for the Te Roto device greater than 2.5m are carried out in the summer to reduce ground water seeping into the excavation.

Construction of the Te Roto soakage device is not expected to have a significant effect on regional or local groundwater levels since the device simply replicates the nearby device that is serving the same function. The device will not cause any effect on regional or local flood storage either.

Figure 21 shows samples from bore hole 106. Note the silty nature of the first 1m followed by gravels (with no matrix). Test pit 108 showed the gravels to be in a silty sandy matrix.

Figure 21: Bore hole 106 samples

This stream has no tributary network so fish passage is not required; this is in line with the recommendations given in Technical Report No 12 (Aquatic Ecology).

The extreme (i.e. super-design) event (defined as Q_{100} plus climate change plus 50%) causes the overflow culvert to activate, however there is no risk of water going over the Expressway.

7.2.9 Andrews Culvert

As described in section 6.6.10, there is no defined channel associated with this catchment. The proposed culvert maintains the connection between the upstream catchment and downstream soakage area. The flows involved are small and no significant change is expected. The effects of the Expressway on the flow regime are minor, this being that the water flowing off the catchment will be collected against the Expressway embankment instead of against the railway embankment.

7.2.10 Grahams Culvert

As described in section 6.6.11, there is no defined channel associated with this catchment, however in large storm events sheet flow may accumulate against the Expressway embankment, and need to be transferred to the other side. The proposed culvert merely maintains the connection between the upstream catchment and downstream soakage area. The flows involved are small and no significant change is expected. The effects of the Expressway on the flow regime are minor; this being that the water flowing off the catchment will be collected against the Expressway embankment instead of against the railway embankment.

7.2.11 Ōtaki River Bridge

The Ōtaki River catchment has been the subject of a specific hydraulic study. As such the sizing and assessment of the bridge and flood plain is detailed in Technical Report N^{o} 9[76].

Fish passage is required on the Ōtaki River, however bridges do not affect the ability of fish to migrate past them, so this is not an issue for the Project.

7.2.12 Mangaone Culverts and Bridges

The Mangaone catchment has been the subject of a specific hydraulic study. As such the sizing and assessment of the bridge, culverts and flood plain is detailed in Technical Report N^{o} 9.

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR11 included in Appendix 5. This includes embedding the invert, creation of a low flow channel, increased roughness of the low flow channel (ie angular rock substrate not smooth concrete), and boulder rows to locally slow flow and create variation. A particularly important detail to note is that the downstream invert is at or below the level at which water ponds in the downstream riprap.

7.2.13 School Culvert

As described in section 6.6.14, the School Catchment is a sub-catchment of the Mangaone Stream and the two are assessed together and detailed in Technical Report N^{o} 9.

[76] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012

7.2.14 Gear Culverts and Settlement Heights Culvert

As described in section 6.6.15, the Gear and Settlement Heights streams are within 300m of each other and, in flood conditions, share a common tail water condition and headwater pond.

Under the existing situation, during a flood event, the railway embankment causes water to head up and create a pond. The Expressway embankment goes through this ponded area, and whilst the volume of water displaced is not significant, there will be an increase in the level of the ponded water on the upstream side of the Expressway. This is due to the hydraulic requirement for there to be a level difference between the up and down stream end of a culvert in order for water to flow through it.

The design requires 300mm of level difference between the up and downstream ends. As such, the level of the ponded water on the upstream side of the Expressway will be 300mm higher, (in a Q_{100} event) than previously. This effect is shown in Figure 22.

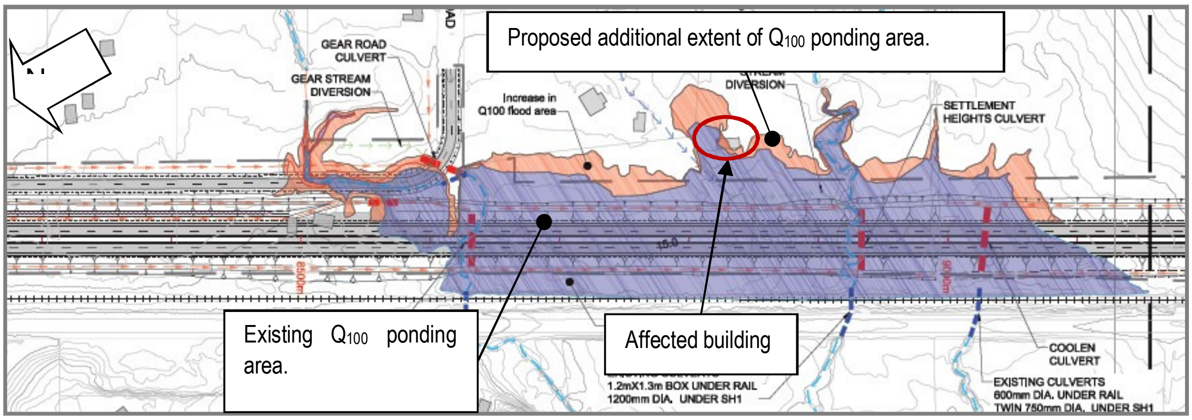

Figure 22: Gear/Settlement Heights Q_{100} ponding area

The area of increased ponding will be located largely in areas of pasture. However, as can be seen in Figure 23, there is an existing farm storage building, part of which is already affected by flooding, that will have an increased depth and area of flooding in a Q_{100} event (orange shows the additional Q_{100} ponding area; blue shows the existing Q_{100} ponding area).[77] While smaller events have not been modelled, it is reasonable to conclude that ponding will increase for any given storm (up to 300 mm), and be more frequent for a given pond level. Information about the floor level and specific use of this building is currently

[77] It is acknowledged that the approach used here for assessing the flood hazard effects of the Expressway on buildings, whether these effects are acceptable and whether mitigation is required, differs from Technical Report No 9: *Assessment of Hydraulic Effects for Major Watercourse Crossings* (Opus, 2013)

In this report the standard flood test applied throughout the Project area has been the 1% AEP flood adjusted for possible future climate change effects, and mitigation is recommended accordingly. Larger events have not been assessed other than by checking a Q_{100}+CC+50% flow.

Technical Report No 9 models less frequent storms (e.g. 0.5% and 0.2% AEP) to address specific catchment issues – for example, the flood storage facility on the Mangapouri Stream – but still uses the 1% AEP event as a basis for concluding that no additional mitigation is required.

unavailable, so it is not possible to define a specific thresh-hold where flood effects become significant. Further reduction of culvert headwater depth is extremely difficult by engineering means; one option might be to resolve this issue through negotiations with the land-owner about raising or relocation, bunding, compensation, etc. In the absence of a satisfactory arrangement the residual effect of the Expressway on this property owner must be considered minor-moderate.

Figure 23: Affected Building

In the extreme (i.e. super-design) event (defined as Q_{100} plus climate change plus 50%) the water level upstream of the Expressway will increase by a further 400mm. This means that there will be some water encroaching onto one trafficked lane, probably about 10-20mm in the outer lane near the shoulder. As the water is not expected to flow over the crown of the road the velocity of the water is expected to be effectively zero. The water level is expected to recede below the level of the lanes within 30 minutes of the end of the storm event.

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR11 included in Appendix 5. This includes embedding the invert, creation of a low flow channel, increased roughness of the low flow channel (ie angular rock substrate not smooth concrete), boulder rows to locally slow flow and create variation. A particularly important detail to note is that the downstream invert is at or below the level at which water ponds in the downstream riprap.

7.2.15 Coolen and Avatar Culverts

As described in section 6.6.16, the Coolen and Avatar Catchments have no defined channel and the culverts are not situated in topographical low points. As such there are no significant headwater ponds associated with these culverts.

The culverts have been sized to allow the existing flows under the rail embankment to continue. Flows in excess of this are diverted to the Settlement Heights culvert. This is no different to the existing situation.

In the extreme (i.e. super-design) event (defined as Q_{100} plus climate change plus 50%) any water that does not go through the culverts will bypass and continue north to the Settlement Heights Culvert (see above). This is similar to the existing situation.

7.2.16 Edwin Culvert

As described in Section 6.6.17, the Edwin Catchment is a nominal catchment and the proposed culvert is included to provide ecological flows to the 150m long, downstream stream reach.

From a flood water perspective this culvert is not needed as all flood flows in this area are allowed for in the design of the Jewell culvert. The effect of inclusion or exclusion of this culvert is insignificant from a stormwater viewpoint, however it is understood that there are ecological reasons for including it.

7.2.17 Jewell Culvert

This is a significant culvert and, as described in section 6.6.18, it is located just downstream of existing SH1 and railway culverts.

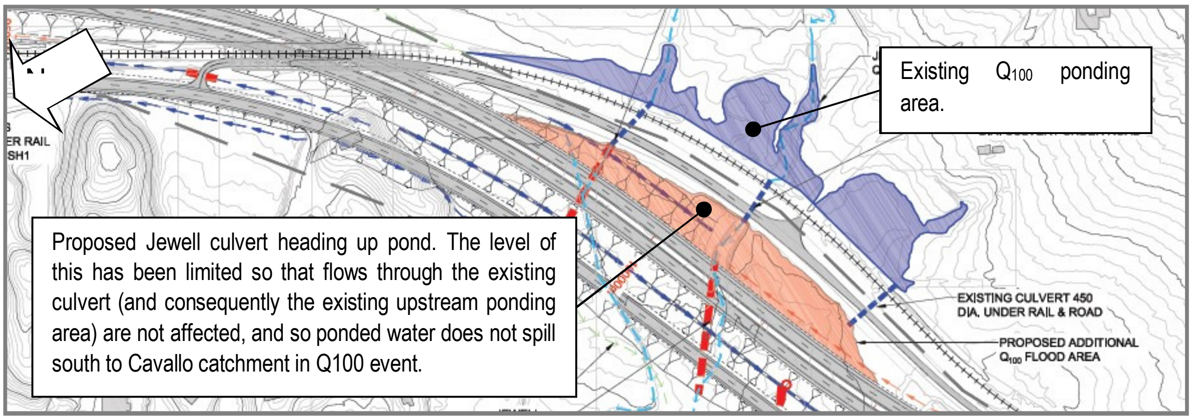

Figure 24: Jewell Q_{100} ponding area

The Expressway culvert has been designed to not affect the flows through the existing upstream culverts. This has been done by limiting the Q_{100} water level on the upstream side of the proposed Jewell culvert.

In the extreme (i.e. super-design) event (defined as the Q_{100} flow plus climate change plus 50%) the water level upstream of the Expressway increased by approximately 600mm. At chainage 10400m (which is 350m south of the culvert) water can be expected to encroach onto the shoulder and the first trafficked lane for a period of about one and a half hours (depending on the duration of the storm event), with the second trafficked lane remaining clear of flood water. The water is not ponding (as this is not a low point in the road rather the high point in the swales) but is flowing south to the Cavallo culvert. The amount of water flowing south to the Cavallo culvert is estimated between 1 to $4m^3/s$ (depending on detail design) at a velocity between 0.5 and 1.5 m/s. No significant damage to the road is expected. Despite the uncertainty in their quantum, we are satisfied that the effects of flow transfer between these catchments will be trivial, with no significant damage to property or infrastructure, and the duration short.

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR11 included in Appendix 5. This includes embedding the invert, creation of a low flow channel, increased roughness of the low flow channel (ie angular rock substrate not smooth concrete), and boulder rows to locally slow flow and create variation. A particularly important detail to note is that the downstream invert is at or below the level at which water ponds in the downstream riprap.

7.2.18 Cavallo and Cording Culverts

As described in section 6.6.19, the Cavallo and Cording Catchments have no defined stream channel, and are nominally defined by the areas draining to a series of small culverts under railway embankment and SH1.

The main proposed culvert in this area is the Cavallo Culvert and this has been sized so there is no effect on the flows in the culverts going under SH1 or the railway.

The proposed culvert identified as the Cording Culvert is an extension to an existing SH1 culvert. If this culvert turns out not to be needed, the flow is already allowed for in the size of the Cavallo Culvert.

In the extreme (i.e. super-design) event (defined as Q_{100} plus climate change plus 50%) there will be some overflow from the Jewell catchment into this catchment (as described above). The result is that the Expressway is at risk of water flowing over it. The flow over the Expressway could be up to 2 to 4m^3/s. The flow would be centred at the Expressway low point at distance 10900m, with maximum depth of 250 to 300mm. The flow width would be over 150 to 200m of road length, with an approximate velocity of 1 to 1.5m/s. This would not be considered passable for normal cars and would be expected to last for 15 to 30 minutes.

Taking a conservative approach, fish passage is proposed to be included in the Cavallo Culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR10 included in Appendix 5. This includes embedding the invert, the creation of resting pools within the culvert between rock ramps and by ensuring that the downstream culvert invert is at or below the level at which water ponds in the downstream riprap.

7.2.19 Awatea Culvert

As described in section 6.6.20, the proposed Awatea Culvert replaces the existing SH1 culvert. The proposed culvert is larger than the existing culvert and the possible effect was that water would be released downstream at a higher rate than the current situation.

We assessed the before and after hydraulic situations and found that the proposed larger culvert has a much lowered headwater level however this does not significantly affect the ponding level upstream of the railway culvert. This is because the railway culvert is relatively small compared to the flows and the ponding level continues to be controlled by the over-topping of the railway line.

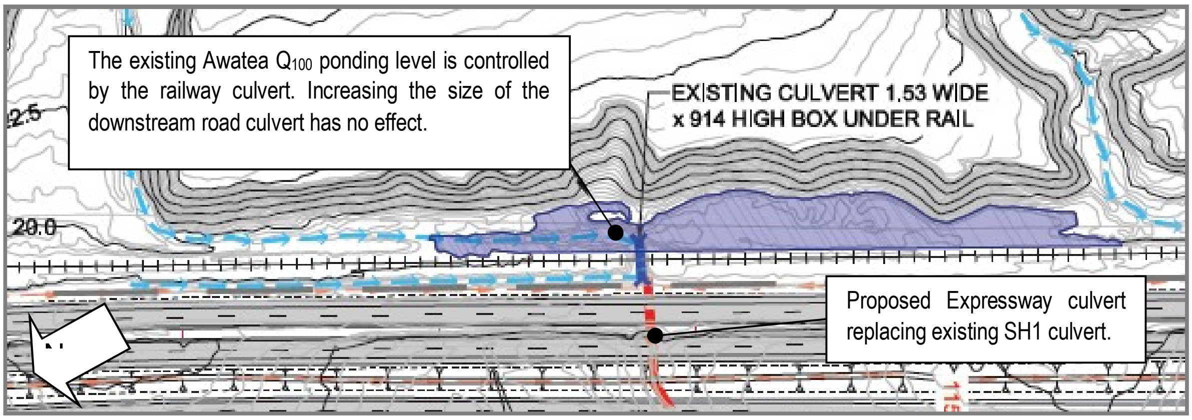

Figure 25: Awatea Q_{100} existing pond area

The flow continues to be controlled by the railway culvert and therefore the water is still released at the same rate. A larger culvert under the Expressway is needed so that the Q_{100} flows go under the Expressway, not over it.

In the extreme (i.e. super-design) event (defined as Q_{100} plus climate change plus 50%) an estimated peak of 6.8m^3/s (depending on the final culvert size) of water will flow over the Expressway, however as this is not a low point in the proposed road, the overflow will be very spread out. The main direction of flow will be south along the road, spilling over the crest (as a side weir). Thus the depth is not expected to be more than 100mm in the centre so the two trafficked lanes remain passable. This is similar to the existing situation and is expected to last for up to one and a half hours depending on the duration of the storm event.

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR10 included in Appendix 5. This includes embedding the invert, the creation of resting pools within the culvert between rock ramps and by ensuring that the downstream culvert invert is at or below the level at which water ponds in the downstream riprap.

7.2.20 Kumototo Culvert

As described in section 6.6.20, the proposed Kumototo Culvert replaces the existing SH1 culvert. The proposed culvert is larger than the existing culvert and the possible effect was that water would be released downstream at a higher rate than the current situation.

We assessed the before and after hydraulic situations and found that the proposed larger culvert has a much lowered headwater level than the existing culvert and that this does significantly affect (reduce) the ponding level upstream of the railway culvert. This is because the railway culvert is relatively large compared to the flows and so is not a constriction to the flow.

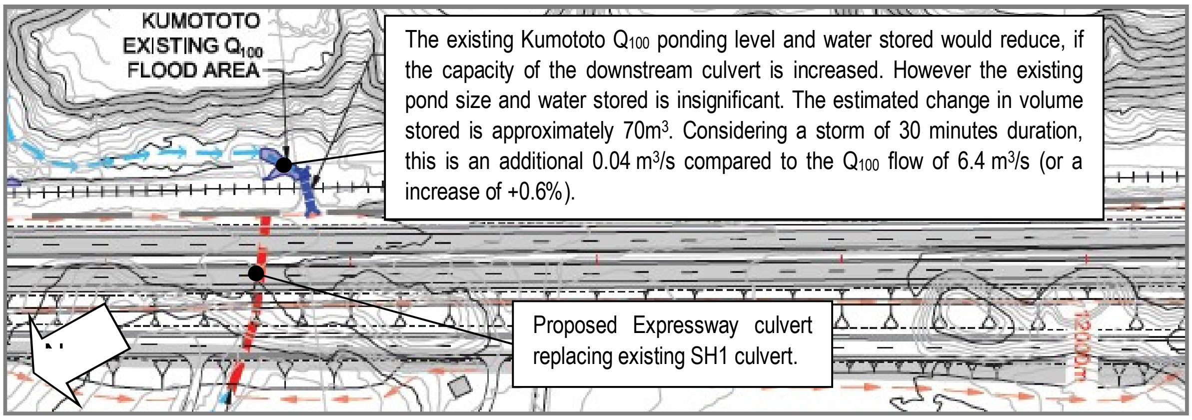

Figure 26: Kumototo Q_{100} existing pond area

To assess the significance of this, we investigated how large the ponding area was behind the railway embankment and how much water was being stored there. We found that the topography upstream of the railway embankment is steep and the volume of storage is very small. In our opinion the change in the volume of water that is stored behind the railway embankment is insignificant and the effect on downstream flooding level will also be very close to zero.

In the extreme (i.e. super-design) event (defined as Q100 plus climate change plus 50%) there will be an estimated peak of 1.7m^3/s of water flow over the Expressway, however as this is not a low point in the proposed road, the overflow will be very spread out. The main direction of flow will be south along the road, spilling over the crest (as a side weir). Thus the depth is not expected to be more than 100mm in the centre two trafficked lanes so remain passable. This is similar to the existing situation and is expected to last up to one hour depending on the duration of the storm event.

Fish passage is proposed to be included in this culvert by using a detail similar to that shown on drawing 5/2664/1/6504/DR10 included in Appendix 5. This includes embedding the invert, the creation of resting pools within the culvert between rock ramps and by ensuring that the downstream culvert invert is at or below the level at which water ponds in the downstream riprap.

7.3 Road runoff attenuation and treatment

This section describes the design approach and effects of the Project-wide road runoff management. It also considers specific locations where the road runoff management differs from the typical approach.

7.3.1 Attenuation swales – Project-wide road runoff management

We propose to use attenuation swales along approximately 55% of the Project route to collect, convey, treat and attenuate the rain water that runs off the road surface. These swales are wider than conventional treatment swales, and contain plant species appropriate to a wet environment.

Conventional swales provide treatment through physical filtration as shallow surface stormwater flow percolates through vegetation (the grass height being higher than the flow depth). This will be true also for the attenuation swales for small flows (up to the ED discharge rate), however for larger flows up to the Q_{100} event the swales will effectively become elongated ponds or wetlands. While the treatment mechanism is different, the extended detention available will still provide a high degree of treatment, for a considerably wider suite of storms than just the defined water quality storm.

Our approach has been to design an attenuation swale that is repeatable with simple and robust hydraulic controls, which are relatively easy to construct and maintain (as the hydraulic control is simple and the same in each bund of a given swale). This has led to swales that have the capacity to capture 100% of the Q_{100} storm road runoff and hydraulic controls that release the captured water at the stream erosion control (i.e. extended detention) rate, with the water quality volume released over 24 hours.

Since the swales contain only a single hydraulic control at any given location, the Q_{100} event will be captured and discharged through the same hydraulic control as the ED event. Therefore, conservatively assuming zero soakage, the Q_{100} volume will take approximately 7 days to drain down.

The advantage of this approach is that the same simple hydraulic control can be used at each bund within a given swale. This reduces potential errors and time during construction and provides sections of wetland environment. A typical detail of the hydraulic control and bund within the attenuation swale is shown on drawing 5/2664/1/6504/DR15 included in Appendix 5. The relevant section is shown in Figure 27 below.

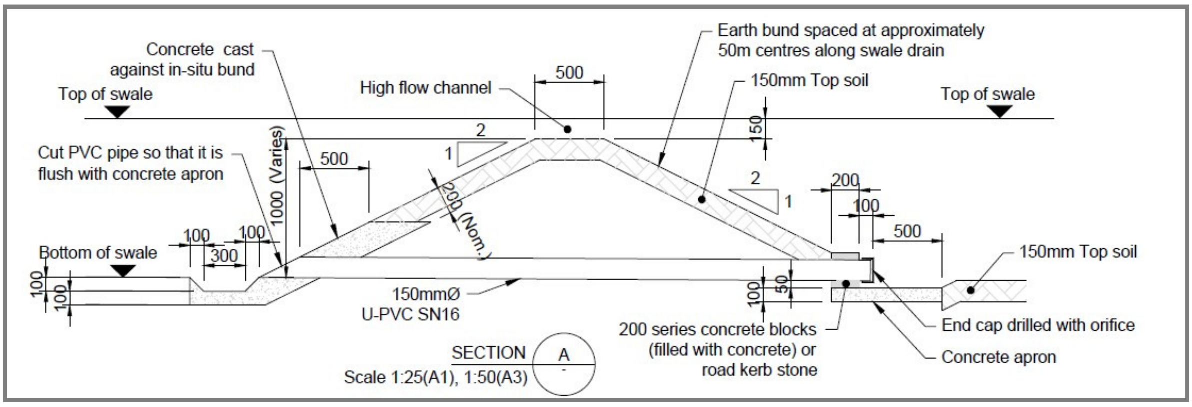

Figure 27: Attenuation bund typical detail

The spacing of the bunds and the orifice size (controlling the flow of water through the bund) is specific to each swale run but consistent within each swale.

The water quality effect is specific to each swale but the general result is that the average residence time (the time that the water is in the swale) is greatly increased compared to a non-attenuation swale. This means that the attenuation swales' overall treatment effectiveness will be above the minimum requirements.

The attenuation effect is also specific to each swale but the general result is that the Q_{100} flows are attenuated to below the pre-development flows. The Q_{100} attenuated flow rate ranges from 20% to 80% of the pre-development flow rate.

The limitations of this approach are that it is less economical in urban areas and not practicable where the Expressway is restricted for space (eg around Mary Crest).

7.3.2 Chainage 1000 to 2100 (Railway/Kennedy Wetlands and Taylor Basin)

As described in section 6.7.1, the Expressway cuts through existing sand dunes and an existing wetland. The geometrics are constrained in this area so constantly wide attenuation swales have not been used. Part of the road in this area, drains to the Railway Wetland and part drains to the Taylor Basin; these areas are shown on Figure 17 (section 6.7.1 on page 41). Figure 28 shows a plan of these wetlands.

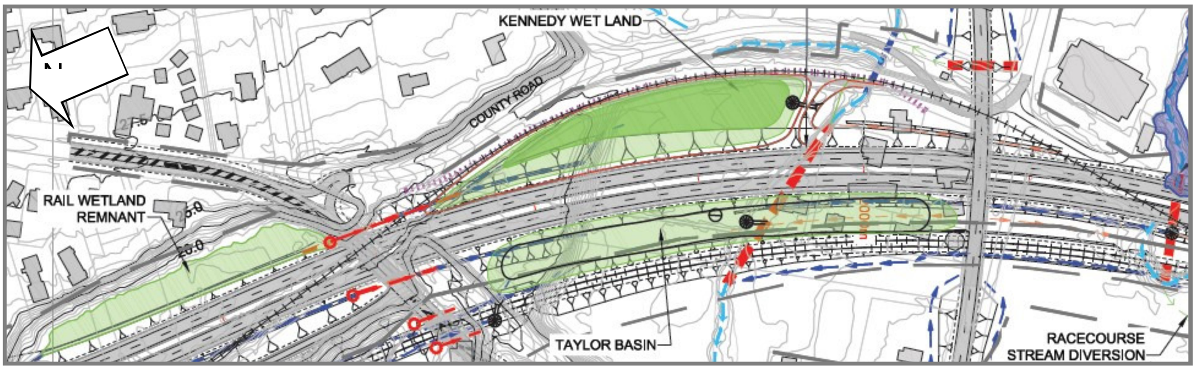

Figure 28: Railway Wetland, Kennedy Wetland and Taylor Basin

The area that drains to the Railway Wetland does so via swales, then goes through the Kennedy Wetland and discharges to the Mangapouri Stream. This section has been designed so that road runoff receives treatment in the swale before getting to the Railway Wetland. The road runoff is then attenuated in the Railway Wetland and the Kennedy Wetland.

The loss of part of the existing Railway Wetland is significant in terms of the existing stormwater attenuation. This, and the road runoff into the Railway Wetland has been incorporated into the Mangapouri flood model and the volumetric effects are described in Technical Report No 9 [78].

The other, larger part of the Expressway in this area drains to the Taylor Basin via swales. Once again this section has been designed so the road runoff receives treatment in the swale before getting to the basin. Once in the basin the road runoff is attenuated before being slowly released into the Mangapouri Stream.

Taylor Basin is generously sized and we have been able to apply the same management philosophy to this attenuation area as we have done with the attenuation swales. That is to say that the pond contains a single outlet control for all storm events, and all water (up to

[78] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012

the Q_{100} (2090) event) running to the Taylor Basin is captured and released at the extended detention rate.

As the post-development catchment area is larger than the pre-development catchment, the reduction in flows is not as dramatic as areas where the pre- and post-development catchment are the same, however we are still achieving a post-development flow that is less than 80% of the pre-development flow.

We propose that the outlet from Taylor Basin is a simple manhole outlet as per Figure 29.

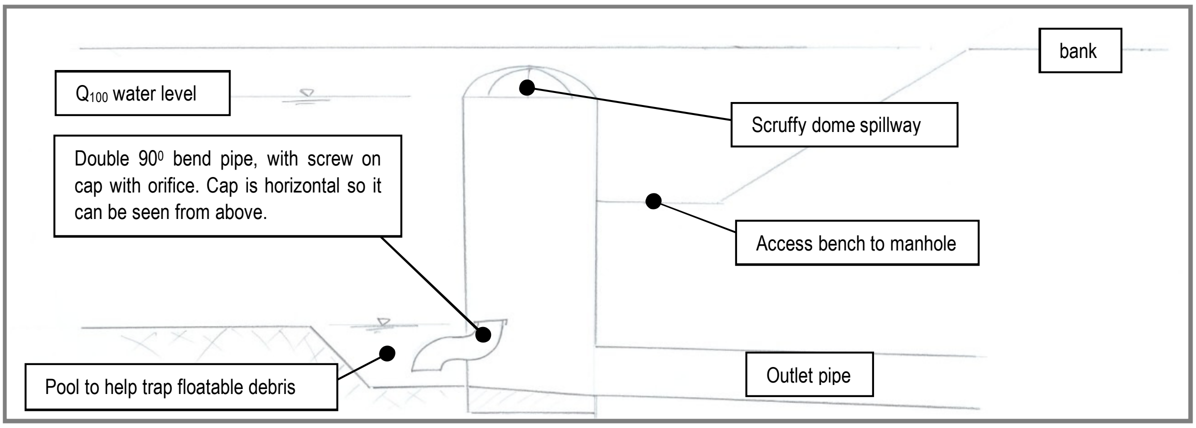

Figure 29: Taylor Basin outlet structure

7.3.3 Chainage 2650 to 3200 (Soakage behind the Ōtaki River stop bank)

This area would have originally (prior to human intervention) drained to the Ōtaki River. The Ōtaki River stop bank now prevents this natural drainage pattern, so now any water that runs off the land collects behind the bank and soaks into the ground. See Figure 30.

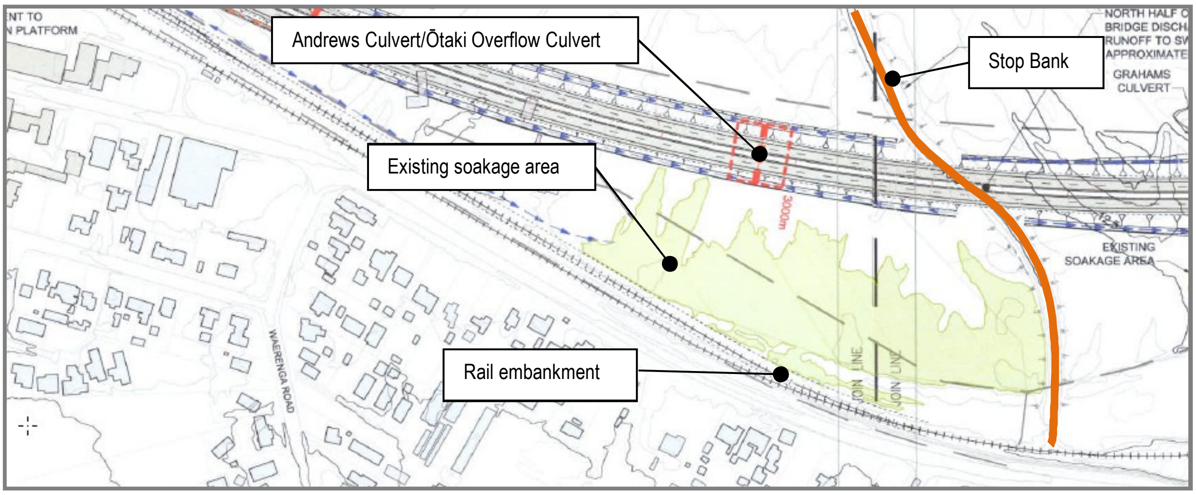

Figure 30: Soakage behind the Ōtaki River stop bank

As the receiving environment for this section of road is a soakage area, attenuation is not necessary. The soakage area is large compared to the areas draining to it and is not easily accessible for development.

The minor increase in flow from the road to this area will have minimal effect. From a quality perspective, the water that runs off the road surface will be collected and treated in swales before being discharged to the soakage area.

Figure 31: Spoil from test pits 109 and 110 (cobbles in a sandy matrix)

During the excavation of test pit 109[79], a slight inflow of ground water was encountered at about 3.5m below ground level, (the test pit was dug during Jan 2011). Bore hole 106 shows that the ground water depth was 4.8m deep at the end of March 2011.

Figure 32: Bore hole 106 samples

Figure 32 shows samples from bore hole 106. Note the silty nature of the first 1m followed by gravels. Figure 31 shows the spoil from test pits 109 and 110, which is gravels and cobbles in a sandy matrix. This indicates that soakage rates are good in this localised area.

7.3.4 Chainage 3200 to 5200 (Expressway draining to the Ōtaki River)

The road area draining to the Ōtaki River will be treated by swales. The swales are long and the average residence time is greater than the minimum requirement of nine minutes for the water quality flow.

As the Ōtaki River has a large catchment of 200 to 300 km^2 and the discharge point is in the downstream quarter, we do not propose to attenuate runoff from the road. We consider the effect of the small increase in flows from the Expressway to be negligible due to both the location of the discharge (relative to the catchment) and the large quantity of flow in the Ōtaki River.

[79] As described in report: *PN441 – Peka Peka to North Ōtaki SH1 Upgrade - Geotechnical Factual Report* ref 60191484, AECOM, 2011

We also consider the cumulative effects negligible as no development is proposed in the majority of the Ōtaki River catchment.

7.3.5 Chainage 3200 to 4200 (the Ōtaki River Bridge)

Runoff that is collected from the Ōtaki River Bridge is piped back to each abutment, where it discharges to swales to receive treatment. See Figure 33.

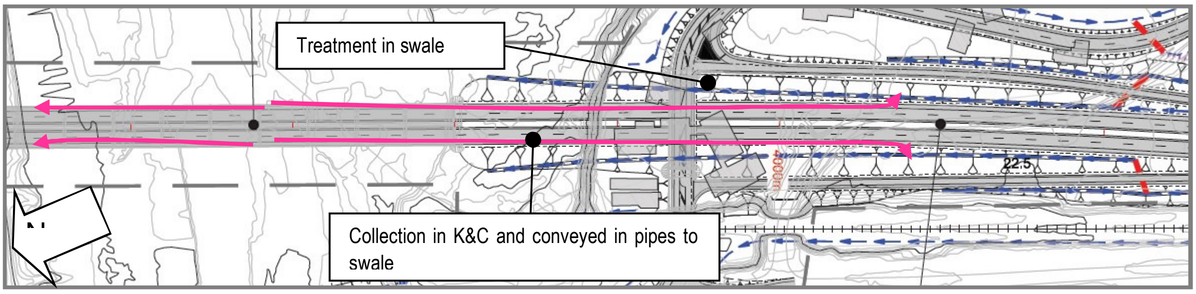

Figure 33: Road runoff from Ōtaki River Bridge

Particularly on the south side of the bridge (where the swales already have water flowing in them from the south), we have been careful to ensure that the water achieves the minimum residence time before being discharged to the Ōtaki River. Our calculations show that the minimum residence time is met approximately twice over (15 to 20 minutes), with a depth of water (in the water quality flow) of about 400mm and a velocity of 0.2m/s. It is important that these swales are planted with species such as Oioi that can stay vertical in these velocities and grow to a height greater than the flow depth.

7.3.6 Chainage 9700 to 10200 (Valentine Basin at Mary Crest)

As described in section 6.7.3, the Expressway threads between the existing SH1 and some native bush. The rainwater that runs off the road will be collected and treated in swales. The swales will then discharge to Valentine Basin where flow will be attenuated.

The area allocated for this attenuation basin is sufficient to achieve a post-development flow that is less than the pre-development flow. As such we would expect this to have a small positive effect on catchment flood flows.

8 Residual Effects?

This section summarises the residual effects, discusses their significance and comments on environmental compensation.

8.1 What are the residual effects

This section summarises the stormwater-related effects described in section 7 that have not been designed-out.

8.1.1 Construction-Related Effects

Best practice (BPO) erosion and sediment control measures will be implemented, maintained and monitored throughout the Project. Site soil conditions suggest that BPO ESC practices are likely to be highly effective, however (as normally occurs on any earthworks site) there will still be some small residual release of sediment. This residual effect is likely to be less than minor, but will be further assured by consent conditions requiring device inspection and ecological monitoring.

8.1.2 Waterway crossings

The potential effects associated with waterway crossings are:

- changes to the upstream flood levels (including outside of the designation)
- changes to the peak flow that is discharged downstream
- changes to the ability of fish to migrate and
- changes to overland flow path in extreme (i.e. super-design) events[80]

Table 9 summarises our assessment of residual effects (after proposed mitigation) for each waterway crossing. The residual effects (i.e. those that have not been designed out) have been highlighted in blue. These are discussed further in section 8.2.

Table 12: Summary of waterway crossing residual effects[81]

Waterway	Upstream flood level in Q_{100} storm	Peak flow discharged downstream in Q_{100} storm	Overland flow path in extreme (i.e. super-design) events	Ability of fish to migrate
Greenwood	See Technical Report No 9[82]			No change
Waitohu				No change
Waitohu tributary				No change
Te Manuao	See Technical Report No 9			NA

[80] Extreme events defined by GWRC as the Q_{100} flow plus climate change plus 50%
[81] Detailed analysis is available in Appendix 4
[82] *Peka Peka to Ōtaki Expressway, Technical Report No 9 Assessment of Hydraulic Effects for Major Watercourse Crossings*, Opus, 2012

Waterway	Upstream flood level in Q_{100} storm	Peak flow discharged downstream in Q_{100} storm	Overland flow path in extreme (i.e. super-design) events	Ability of fish to migrate
Mangapouri				No change
Racecourse	No change	No change	No change	No change
Te Roto	No change	No change	No change	NA
Andrews	No change	No change	No change	NA
Grahams	No change	No change	No change	NA
Ōtaki	See Technical Report No 9			No change
Mangaone	See Technical Report No 9			No change
School				No change
Gear	Increases by 300mm[83]	No change	No change	No change
Settlement Heights	Increases by 300mm[83]	No change	No change	No change
Coolen	No change	No change	No change	NA
Avatar	No change	No change	No change	NA
Jewell	No change	No change	Minor overflow into Cavallo catchment	No change
Cavallo	No change	No change	Increase in flow due to overflow from Jewell catchment[84]	No change
Cording	No change	No change	No change	NA
Awatea	No change	No change	No change	No change
Kumototo	Decrease by approximately 1m	Negligible increase	No change	No change

8.1.3 Increases in impermeable surface

The Expressway increases the area of impermeable surfaces; this has the potential to increase peak flows and downstream flood levels. Our design provides peak-flow attenuation for all catchments that are sensitive to increased flows.

As previously described, our attenuation proposal is to capture the Q_{100} road runoff, and release it at the extended detention rate. This effectively restricts the peak flow to below the existing flow for the Q_{100}, Q_{10} and Q_2 storm events. Table 13 below summarises the

[83] The extent of the existing ponding occurs outside of the designation, so the increase in ponding extent associated with the increase in depth also occurs outside the designation.
[84] As described previously, this is 1 to 4 m^3/s (depending on detailed design) and will last no more than 30 minutes, due to the short time of concentration.

attenuation achieved and any residual effects. The effects that we have not designed out have been highlighted in blue. These are discussed further in section 8.2.

Table 13: Attenuation achieved and residual effects

Chainage (m)	Proposed attenuation device	Post-development flows attenuated to:	Residual effect	Receiving environment
0 to 280	As existing (no change)	NA	None – as existing	North to existing drainage
280 to 400	Attenuation swales	Less than existing flow	None – fully mitigated	Greenwood Stream
400 to 550	Attenuation swales	Less than existing flow	None – fully mitigated	Greenwood Stream
550 to 1000	Attenuation swales	Less than existing flow	None – fully mitigated	Waitohu Stream
1000 to 2100	Attenuation basin	Less than existing flow	None – fully mitigated	Mangapouri Stream
2100 to 2600	Attenuation swales	Less than existing flow	None – fully mitigated	Racecourse Stream
2600 to 3100	None	NA	Increase in flows and volume discharged	Soakage area behind Ōtaki River stopbank
3100 to 4100	None	NA	Increase in flows and volume discharged	Ōtaki River
4100 to 5200	None	NA	Increase in flows and volume discharged	Ōtaki River
5200 to 7500	Attenuation swales	Less than existing flow	None – fully mitigated	Mangaone Stream
7500 to 8600	Attenuation swales	Less than existing flow	None – fully mitigated	Gear Stream
8600 to 9050	Attenuation swales	Less than existing flow	None – fully mitigated	Settlement Heights Stream
9050 to 9400	Attenuation swales	Less than existing flow	None – fully mitigated	Coolen Culvert
9400 to 9700	Attenuation swales	Less than existing flow	None – fully mitigated	Avatar Culvert
9700 to 10200	Attenuation basin	Less than existing flow	None – fully mitigated	Jewell Stream
10200 to 10400	Attenuation swales	Less than existing flow	None – fully mitigated	Jewell Stream
10400 to 11150	Attenuation swales	Less than existing flow	None – fully mitigated	Cavallo Stream
11150 to 11550	Attenuation swales	Less than existing flow	None – fully mitigated	Awatea Stream

Chainage (m)	Proposed attenuation device	Post-development flows attenuated to:	Residual effect	Receiving environment
11550 to 11700	Attenuation swales	Less than existing flow	None – fully mitigated	Kumototo Stream
11700 to 12250	Attenuation swales	Less than existing flow	None – fully mitigated	South to M2PP drainage

8.1.4 Increase in pollutants washed into the environment

The Expressway increases the area of trafficked surface and will convey, long-term, increased traffic volume. As we are proposing to treat all road runoff from the Expressway, the majority of water-borne pollutants will be captured before they enter the receiving environment.

There is currently no road formal runoff treatment associated with the existing SH1, and pollutants generated here are not formally removed from runoff before it is discharged into the receiving environment. However there will be some incidental treatment in the existing drains.

As the Project will transfer the majority of traffic from the existing SH1 to the formally treated Expressway, the overall levels of pollutants discharged to the receiving environment from the two roads combined is expected to reduce.

Road runoff treatment is provided by swales along the Project. The swales are designed in accordance with NZTA's standards, which are currently regarded as best practice in the industry. This approach is regarded as the best practicable option (BPO) and swales designed, built and operated to NZTA's standards are generally considered to remove 70 to 80%[85] of suspended solids and a proportion of other associated pollutants on a long term average basis. Moreover, because of the long detention time provided in the swales, enhanced treatment should occur. Conversely, we can infer that up to 25% of contaminants may not be removed. However, as discussed above, when considering the Project as a whole, there is expected to be an overall decrease in pollutants entering the environment collectively from the two roads. This is a positive (albeit unquantified) effect.

8.2 Significance of the residual effects

The potential stormwater effects of the Project have largely been designed out though appropriate sizing and design of culverts, and through using best practice for road runoff management. The residual effects, as identified in section 8, and the significance of them is commented on in Table 14.

[85] See NZTA SWTS table 8-1 on page 89 and reference to American study on page 93

Table 14: Significance of residual effects

Residual effect	Significance
300mm increase in the Q_{100} headwater pond level at the Gear and Settlement Heights Culvert.	This effect has significance for the building (identified in section 7.2.14) that is already in this flood zone. By increasing the culvert headwater depth, this building will be subject to a greater depth and frequency of flooding. The significance of this will depend on the building type, use and level of the floor.
Decrease in headwater depth behind the railway culvert on the Kumototo Stream, and associated increase in downstream flow.	As discussed in section 7.2.20, the increase in flow is extremely small, as the volume of water temporarily stored behind the railway embankment is minor. The significance of this effect is extremely minor as the peak flow is increased by about half a percent and due to the short time of concentration, there is no change in the volume of water discharged downstream.
Increase in flows and volume discharged to the soakage area behind the Ōtaki River stop bank.	The significance of this is extremely minor. The soakage area is relatively large and all indications are that the soakage conditions are very good (as discussed in section 7.3.3). It is possible that the top 1m of topsoil may have a low permeability; if this is the case (and surface water is deemed to be a problem) then a shallow soakage trench could be construction to better discharge water to the extensive sand and gravel layers below.
Increase in flows and volume discharged to the Ōtaki River.	The significance of this is extremely minor. As discussed in section 7.3.4, the increase in flow and volume of water to the Ōtaki River is negligible compared to the flow in the river.

Mitigating the residual effects that have significance is discussed below.

8.3 Potential option for mitigation of residual effects

Table 14 in the previous section shows there is only one residual effect of any significance, this being the increased flood risk to a farm storage building upstream of the Gear/Settlement culverts. This matter could be resolved through direct negotiation with the property owner, and might include measures such as building raising or relocation, local stop-banking, or compensation.

8.4 Acceptability of the residual effects

It is our professional opinion that the residual stormwater effects of the Expressway, after application of the mitigation measures described herein, will be less than minor and are acceptable. The sole exception to this is the farm shed at Gear Rd, for which the residual effects are likely to be minor-moderate.

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