REPORT

Tonkin+Taylor

Omokoroa Stage 3 Structure Plan

Conceptual Water Sensitive Design Plan

Prepared for
Western Bay of Plenty District Council

Prepared by
Tonkin & Taylor Ltd

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Table of contents

Executive summary

Western Bay of Plenty District Council (WBOPDC) are in the process of preparing a structure plan for the next phase of development on the Omokoroa Peninsula (Stage 3) (referred to as "Stage 3" or "the site" hereafter). Stage 3 will comprise approximately 4300 new dwellings along with industrial and commercial zones, a Village Centre and new school campus. Beca prepared a stormwater management plan (SMP) for the Omokoroa Peninsula in 2002 and a subsequent addendum in 2017. The Omokoroa SMP encouraged the adoption of water sensitive design (WSD) practices, however, the implementation of such practices to date has been limited.

Tonkin + Taylor (T+T) has been engaged by WBOPDC to prepare a conceptual WSD plan as a supplement to the existing Omokoroa SMP and addendum. The purpose of this WSD plan is to identify how WSD could be implemented in currently undeveloped areas of Omokoroa Stage 3 to increase the uptake of WSD solutions and to provide some guidance to WBOPDC for setting of structure plan rules regarding stormwater management.

Site characteristics

A review of the existing site characteristics was undertaken including a streamwalk assessment. The table below presents a summary of the constraints and opportunities identified for the site.

Constraints
• The stream corridors play an important role in stormwater conveyance, flood storage, amenity and ecological habitat and should be preserved and enhanced to the extent practicable. • Slope instability risk may preclude the use of infiltration and bioretention devices in some areas (unless lined). • Existing flooding issues in the golf course downstream of the site (subcatchment N2).
Opportunities
• The structure plan area is predominantly a greenfield area which provides an opportunity to incorporate WSD to maintain pre-development hydrology and consider alternative approaches such as the use of overland flow channels instead of pipe networks for primary flows. • The site is predominantly relatively flat outside of the stream gully corridors. This is conducive to the use of devices such as swales. • Treatment at-source provides an opportunity to reduce contaminant loading in downstream treatment devices. • There are currently a number of existing ponds/storage areas that can be utilised for stormwater management. • The site contains a number of streams and wetlands with high ecological values. These could be enhanced to regulate stream flows and enhance ecological functions. • There are a number of subcatchments within the site that discharge directly to the Tauranga Harbour. This reduces the need to manage stormwater quantity in these areas where stream erosion is not a concern. • Other than the known flooding issues within the golf course, there are no other known downstream flood risks. • Providing opportunity for on-site infiltration to improve aquifer recharge and stream baseflows. • Removal/modification of artificial fish passage barriers to improve the ability of migrant fish species to access upstream habitat. • The change in landuse from rural land to urban is an opportunity to revert to natural sedimentation loading in freshwater systems and in the harbour if sediment loads during earthworks are carefully managed.

Current stormwater management approach and requirements

The Omokoroa SMP recommends a mix of a conventional drainage system (i.e. pipe, kerb and channel) and a WSD approach (e.g. swales for conveyance instead of pipes) with WSD being the preference in flat areas and areas with lower development densities. The SMP recommends "full capacity" ponds (i.e. sized to provide the stormwater management requirements for the entire subcatchment) as the primary means of stormwater management and as a "backup" to any areas where WSD might be used. With this approach, a total of 17 new stormwater ponds (and enhancement of one existing pond) are proposed by the SMP within Stage 3 with each pond providing water quality treatment, flood attenuation and detention of smaller events to address stream erosion risk. Other recommendations made in the SMP are as follows:

- Preserving natural streams and providing reserve corridors.
- Protection of secondary overland flowpaths as a part of site planning.
- Encourage measures to reduce volume of stormwater runoff.
- Use management measures to minimise the contamination of stormwater runoff.
- The use of management devices such as stormwater ponds, dry detention basins and swales.
- Consideration should be given to the use of low impact design techniques.

WBOPDC has obtained a Comprehensive Stormwater Consent (CSC) for Omokoroa based on the Omokoroa SMP. The Omokoroa CSC sets out the consent conditions for how stormwater shall be managed in Omokoroa.

Cost of water sensitive design vs conventional development

A review of recent NZ-specific literature was undertaken as part of this study to determine whether WSD was more costly than conventional stormwater management. Overall the latest publicly available research shows that WSD devices used as part of a decentralised management approach (e.g. raingardens, swales) are generally more expensive than equivalent end of pipe solutions typically used in conventional stormwater management (e.g. ponds). That said, using WSD as a holistic approach to development, including non-structural controls such as reduced earthworks and less piped infrastructure, can be a more cost-effective solution than conventional development in certain contexts when avoided costs are considered. However, it is difficult to infer potential cost savings in implementing WSD for a given site based on the literature given the high number of variables that have an effect on the costs of WSD (e.g. catchment size, proportion of impervious area, device types etc.). The available research also highlights that some WSD devices have lower life cycle costs than others. Specifically, swales and wetlands have much lower costs than raingardens.

Suitable stormwater management devices

WSD puts emphasis on the use of "green" devices that can be used to meet multiple ancillary objectives beyond just stormwater management (e.g. public amenity, ecological habitat etc.). The following suite of common green stormwater management devices could be used as part of a WSD approach for Stage 3:

- Wetlands
- Bioretention devices
- Swales
- Pervious pavement
- Raintanks/underground detention tanks
- Living roofs

Geotechnical considerations for stormwater management

Given the history of landslides in Omokoroa, the following issues need to be considered during the design of the stormwater management system for Stage 3:

- The use of soak-holes needs to be minimised as per Condition 6.1 of the Omokoroa CSC.
- If active infiltration devices (i.e. devices where stormwater runoff from other impervious surfaces is concentrated and fed directly into subsoils, such as bioretention devices) are used in Stage 3 then site specific geotechnical investigations should be undertaken to determine local soakage and founding conditions. Alternatively, these devices could be constructed with an impervious liner. This would still allow them to provide other stormwater management functions such as detention and water quality treatment without interacting with the underlying groundwater.
- Overland stormwater flow from development sites needs to be managed in a manner that does not increase the risk of landslides. This may include methods such as creating landforms that do not concentrate overland stormwater flow on susceptible slopes and, where possible, undertaking earthworks such that the finished ground surface falls away from slopes and towards an adjacent road or stormwater management system. Where overland flow does discharge down slopes, specific assessment and engineering design of these slopes may be required.
- Where water is proposed to be impounded, such as in stormwater treatment wetlands, geotechnical investigations will need to be undertaken as part of the design. If existing pond areas are retrofitted into treatment wetlands, then geotechnical assessments of existing embankments, adjacent slopes and underlying ground conditions will be required as part of the wetland design.

Water sensitive design philosophy

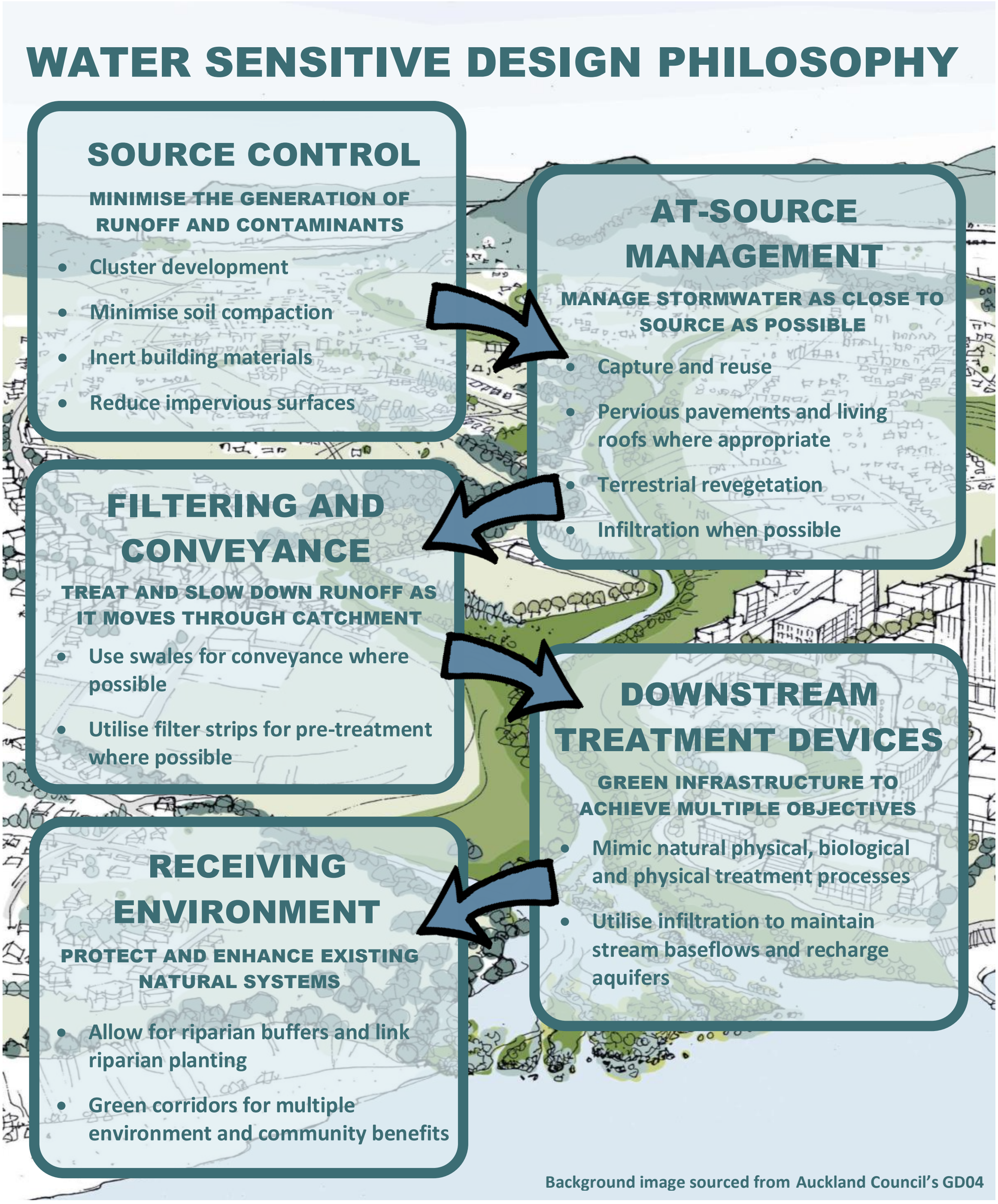
Water sensitive design (WSD) aims to minimise hydrological and ecological impacts as a result of urbanisation and is defined in Auckland Council's WSD guidance document (GD04) as:

"An approach to freshwater management, it is applied to land use planning and development at complementary scales including region, catchment, development and site. Water sensitive design seeks to protect and enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities."

The table below summarises some of the key differences in paradigms between a "conventional" and WSD stormwater management approach.

Conventional stormwater management paradigm	WSD paradigm
Use kerb, gutter and reticulated systems to convey water away as quickly as possible to prevent flood effects.	Match pre-development hydrology by minimising the amount of runoff generated, providing multiple opportunities for infiltration/evapotranspiration and promoting dispersed flows across pervious surfaces.
Centralised "end of pipe" treatment methods that focused on total suspended solids (TSS) removal.	Minimise the generation of pollutants and capture of a range of predicted contaminants as close to the source as possible using natural treatment processes.

The figure below summarises the proposed high-level framework for stormwater management in Stage 3 that aligns with a WSD approach. It is presented as a hierarchy of approaches and considerations for development, starting with the most effective top of catchment interventions (source control and at-source management) and finishing with end of catchment interventions such as downstream devices and enhancing the receiving environment. This framework can be used as a starting point to form the general elements of the stormwater treatment train that will deliver the stormwater management outcomes for development of Stage 3.

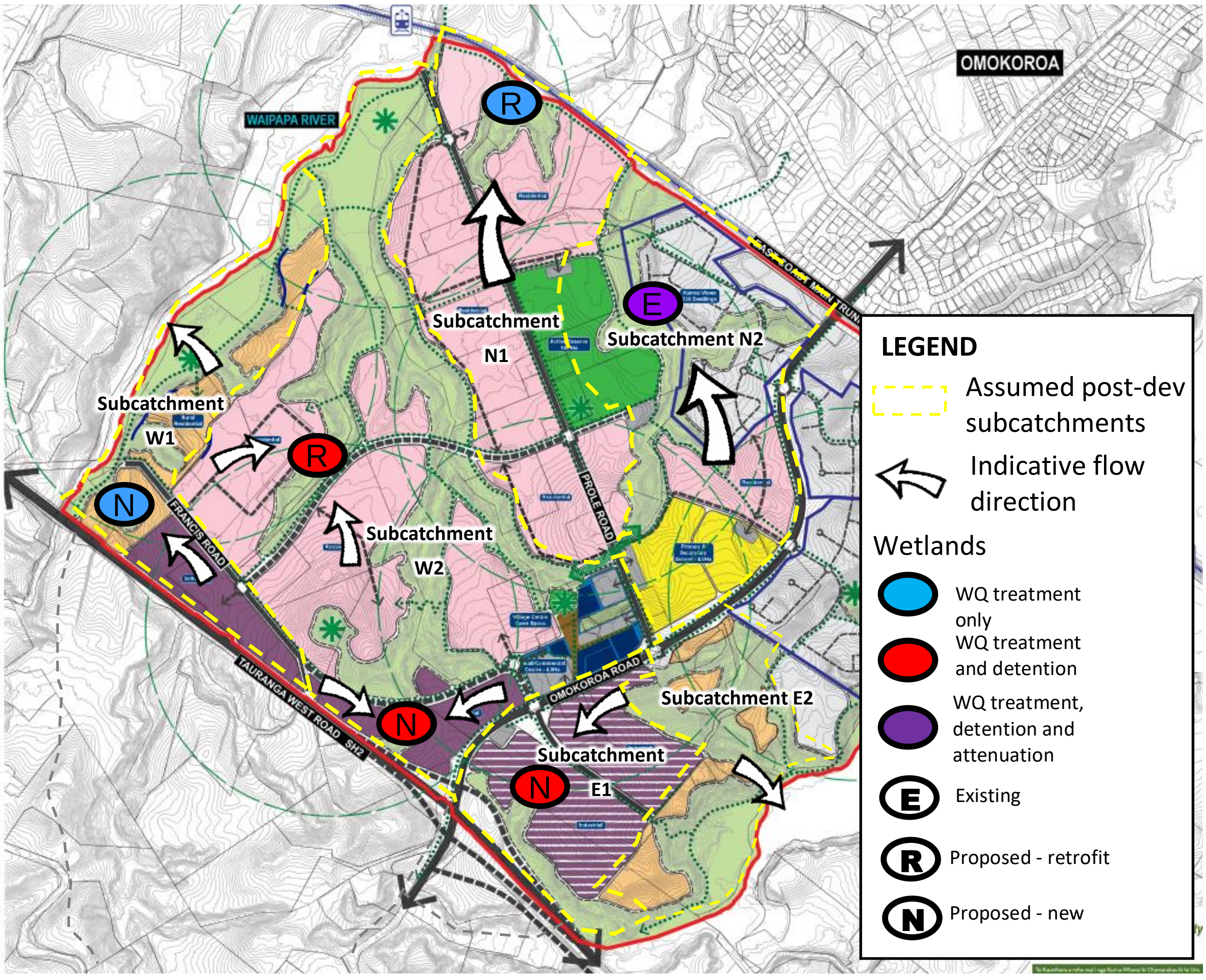


General WSD management approach

To comply with the Omokoroa CSC we propose the following stormwater management objectives for the site:

- Water quality treatment of all impervious surfaces (except the rural-residential zone), with a focus on providing a higher level of treatment for the landuses which will generate most contaminants (e.g. industrial areas and arterial/high use roads).
- Detention of the 90th percentile storm for areas that do not discharge directly to the Tauranga Harbour to mitigate stream erosion risk (subcatchments W2, N2 and E1).
- Attenuation of large rainfall events (i.e. greater than a 90th percentile event) will only be provided where there is private property or infrastructure downstream that would be adversely affected by an increase in flood levels.

Wetlands will be used to provide water quality treatment and detention (where necessary) for industrial areas. For residential areas and commercial areas, the preference is for a decentralised approach. However, given there are some existing informal storage areas that could be retrofitted into treatment wetlands to service the residential areas, it is proposed that these be utilised instead of decentralised devices. However, as a general approach, the number of new wetlands should be minimised as far as practicable. This is because wetlands only treat stormwater at the bottom of the catchment, can result in elevated effluent temperatures and their construction can have adverse effects on existing stream habitat. Based on these principles, it is proposed that three new wetlands are established for managing stormwater for the industrial areas, the two existing storage areas are retrofitted into treatment wetlands to manage stormwater from the residential areas, and the existing pond in subcatchment N2 is retained (refer figure below for proposed locations).



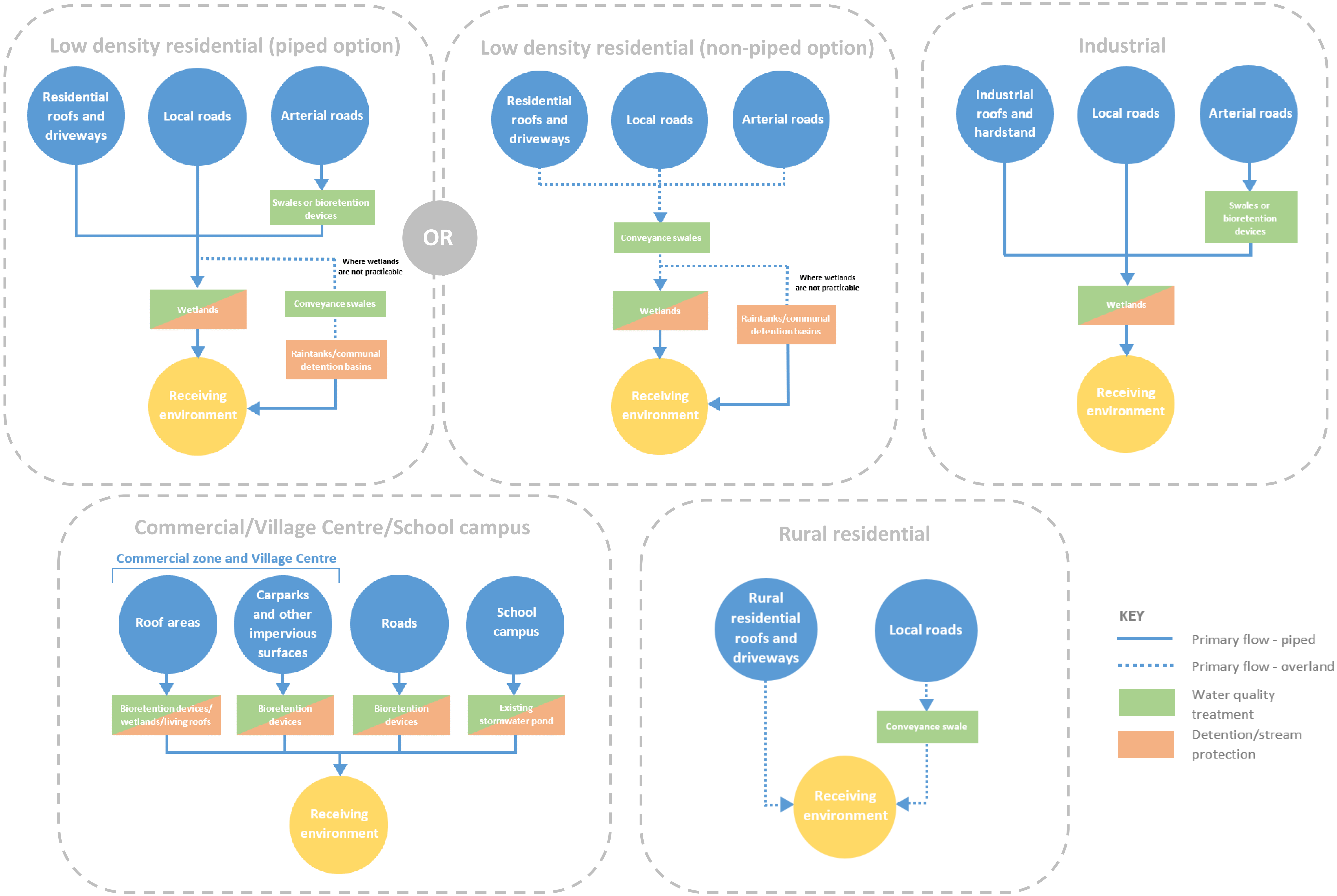
The following approaches are also proposed to be implemented site-wide:

- To minimise the generation of runoff volume it is proposed that maximum impervious limits are added to the Stage 3 structure plan for the low density residential and rural residential zones. Provision could be made for exceedance of the imperviousness limits if onsite mitigation is provided, such as detention/retention using a raintank with non-potable reuse.
- To minimise the generation of stormwater contaminants it is proposed that rules are added to the Stage 3 structure plan requiring “inert” building materials for building exteriors (i.e. no unpainted zinc or copper products unless additional treatment provided onsite).
- If devices that promote active infiltration (such as unlined bioretention devices) are used then they should be located and designed such that they do not increase slope instability risk.
- The use of swales is preferred over raingardens, as swales also provide a conveyance function and are less costly to construct and maintain.
- Green outfalls should be considered for pipe outlets. A green outfall involves a length of naturalised open channel (i.e. with vegetation and roughness elements) to reduce flow velocities and energy before stormwater reaches the receiving stream. Where pipe outlets are located on steep topography then appropriate energy dissipation will need to be incorporated into the outlet to mitigate risk of local scour.
- Overland flow paths for larger rainfall events (i.e. up to a 100 year event) need to be identified and protected as part of the subdivision design stage.
- Gross pollutant traps should be incorporated where possible as a form of pre-treatment for downstream devices. This could be in the form of litter screens in catchpits or end of pipe capture methods.
- Transport links through stream gullies (both vehicular and for pedestrians) should not act as an impediment to the conveyance of flood flows or to fish passage. Stream crossings should be minimised and, where they are required, should be in the form of bridges or fords (for pedestrian crossings) and not culverts.
- The area of impervious surfaces within the road corridor should be minimised. This could be achieved with reduced road widths, only adding footpaths on one side of the road and/or using pervious pavement or gobi blocks for on street parking
- Maximise the use of vegetation throughout the development. Trees in particular should be used where possible in road corridors, stream corridors and other public reserve areas to reduce the temperature of runoff entering the receiving environment. All treatment wetlands should have appropriate planting to reduce temperature effects.

Proposed treatment trains

The table and figure below summarise the proposed treatment trains for each proposed landuse zone in Stage 3. It should be noted that while the treatment trains presented are considered the best practicable option at this time, other approaches and devices could be used to achieve the same stormwater management objectives.

Zone	Conveyance method	Stormwater management devices
Low density residential	Piped option – Primary flow piped, secondary flow overland	• Wetlands where existing storage areas exist • Treatment swales/bioretention devices for arterial roads only • Conveyance swales and raintanks/detention basins where wetlands not practicable
	Non-piped option – Both primary and secondary flow overland	• Wetlands where existing storage areas exist • Conveyance swales on all roads • Raintanks/detention basins may also be required for detention (in addition to conveyance swales) where wetlands aren't practicable
Industrial	Primary flow piped, secondary flow overland	• Wetlands with enhancements such as 'floating treatment wetlands' • Treatment swales/bioretention devices for arterial roads only
Commercial, village centre and school campus	Primary flow piped, secondary flow overland	• School campus managed in existing pond in subcatchment N2 • Bioretention devices for carpark and paved areas • Bioretention devices/wetlands for roof areas • Living roofs can be used in-lieu of stormwater management devices for roof areas
Rural residential	Both primary and secondary flow overland	• Conveyance swales on roads



Low density residential (piped option)
Residential roofs and driveways
Local roads
Arterial roads
Swales or bioretention devices
Where wetlands are not practicable
Wetlands
Conveyance swales
Raintanks/communal detention basins
Receiving environment
OR
Low density residential (non-piped option)
Residential roofs and driveways
Local roads
Arterial roads
Conveyance swales
Where wetlands are not practicable
Wetlands
Raintanks/communal detention basins
Receiving environment
Industrial
Industrial roofs and hardstand
Local roads
Arterial roads
Swales or bioretention devices
Wetlands
Receiving environment
Commercial/Village Centre/School campus
Commercial zone and Village Centre
Roof areas
Carparks and other impervious surfaces
Roads
School campus
Bioretention devices/ wetlands/living roofs
Bioretention devices
Bioretention devices
Existing stormwater pond
Receiving environment
Rural residential
Rural residential roofs and driveways
Local roads
Conveyance swale
Receiving environment
KEY
Primary flow - piped
Primary flow - overland
Water quality treatment
Detention/stream protection

1 Introduction

1.1 Background

Western Bay of Plenty District Council (WBOPDC) is in the process of preparing a structure plan for the next phase of development on the Omokoroa Peninsula. Structure plans provide councils and developers a long-term framework for future growth and development of a particular area. The area between the railway line and State Highway 2, referred to as 'Stage 3' of Omokoroa, is proposed to be converted from rural landuse to a mix of residential, industrial and commercial landuse with approximately 4300 new dwellings proposed. The currently proposed structure plan zoning and transport corridors are shown in Appendix A.

Beca prepared a stormwater management plan (SMP) for the Omokoroa Peninsula in 2002 (Beca, 2002). The Omokoroa SMP mainly focused on areas of Omokoroa north of the railway (i.e. Stages 1 and 2). In 2017 Beca prepared an addendum to the SMP which included Stage 3 of Omokoroa and various updates to hydrological data, statutory documents, proposed landuse etc. (Beca, 2017). While the implementation plan in the Omokoroa SMP encourages the adoption of water sensitive design (WSD) practices, the implementation of such practices to date has been limited. In the 2017 SMP addendum Beca has recommended that the WBOPDC implement other changes necessary to support the implementation of WSD solutions.

WBOPDC has obtained a Comprehensive Stormwater Consent (CSC) for Omokoroa, based on the Omokoroa SMP, which sets out the consent conditions for how stormwater shall be managed in Omokoroa. The Omokoroa CSC was granted by Bay of Plenty District Council (BoPRC) on 14 July 2003 and amended by the Environment Court in 2004.

1.2 Scope and purpose of current study

Tonkin & Taylor Ltd (T+T) has been engaged by WBOPDC to prepare a conceptual WSD plan as a supplement to the existing Omokoroa SMP and addendum. The purpose of this WSD plan is to identify how WSD could be implemented in currently undeveloped areas of Omokoroa Stage 3 to increase the uptake of WSD solutions and to provide some guidance for WBOPDC for setting of structure plan rules regarding stormwater management. The scope of this WSD plan is as follows:

- Identify physical site characteristics with a specific focus on site geology and stream erosion susceptibility and ecological values (Section 2).
- Summary of key site-specific constraints and opportunities for Stage 3 of Omokoroa (Section 3).
- Summary of the current stormwater management approach and requirements for Stage 3 of Omokoroa (Section 4).
- Review of available NZ specific literature on the cost of WSD compared to "conventional" stormwater management (Section 5).
- Summary of potentially suitable stormwater management devices (Section 6).
- Proposed WSD approach for Omokoroa Stage 3 (Section 7), including:
  - Overarching water sensitive design philosophy (Section 7.1).
  - General water sensitive design approach (Section 7.2)
  - Options for alternative treatment trains that align with a WSD approach (Section 7.3).

2 Site characteristics

2.1 Site extent and catchment setting

Stage 3 of Omokoroa extends from State Highway 2 in the south to the railway in the north and is bound by the Waipapa River to the west and Managwhai Estuary to the east. Stage 3 has a total area of approximately 360 hectares. The focus of this report is the areas within Stage 3 that have not been developed. This excludes the areas associated with the Kaimai Views, Neil Group and Goldstones subdivisions. The undeveloped area within Stage 3 is herein referred to as 'the site' and is shown in Figure 2-1.

The site is located across the lower reaches of both the Waipapa River catchment to the west and the catchment draining to Mangawai Estuary to the east (refer Figure 2-2). Both these catchments ultimately drain into Tauranga Harbour. Within the site there are six main subcatchments; two drain to the Waipapa River to the west, two drain under the railway to the north and then to the Waipapa River and two drain to Mangawai Estuary to the east. Each of these subcatchments has been given an alphanumeric ID (E1 for example) for ease of reference.

It is noted that subcatchment W1 and E1 have upstream subcatchments on the southern side of SH2. These are indicated in Figure 2-1 by yellow dashed lines.

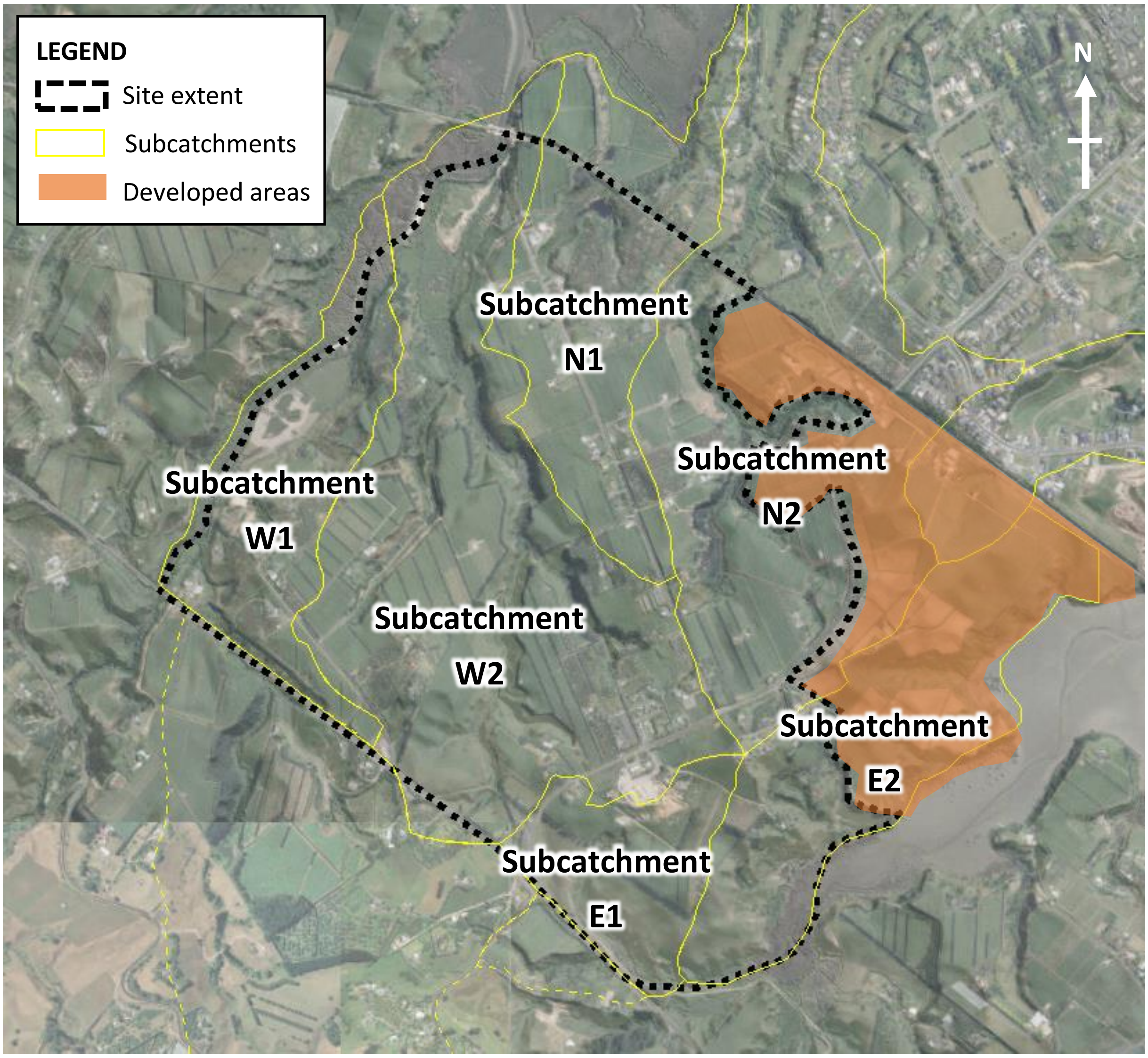


Figure 2-1: Site extent and subcatchments (Beca, 2002)

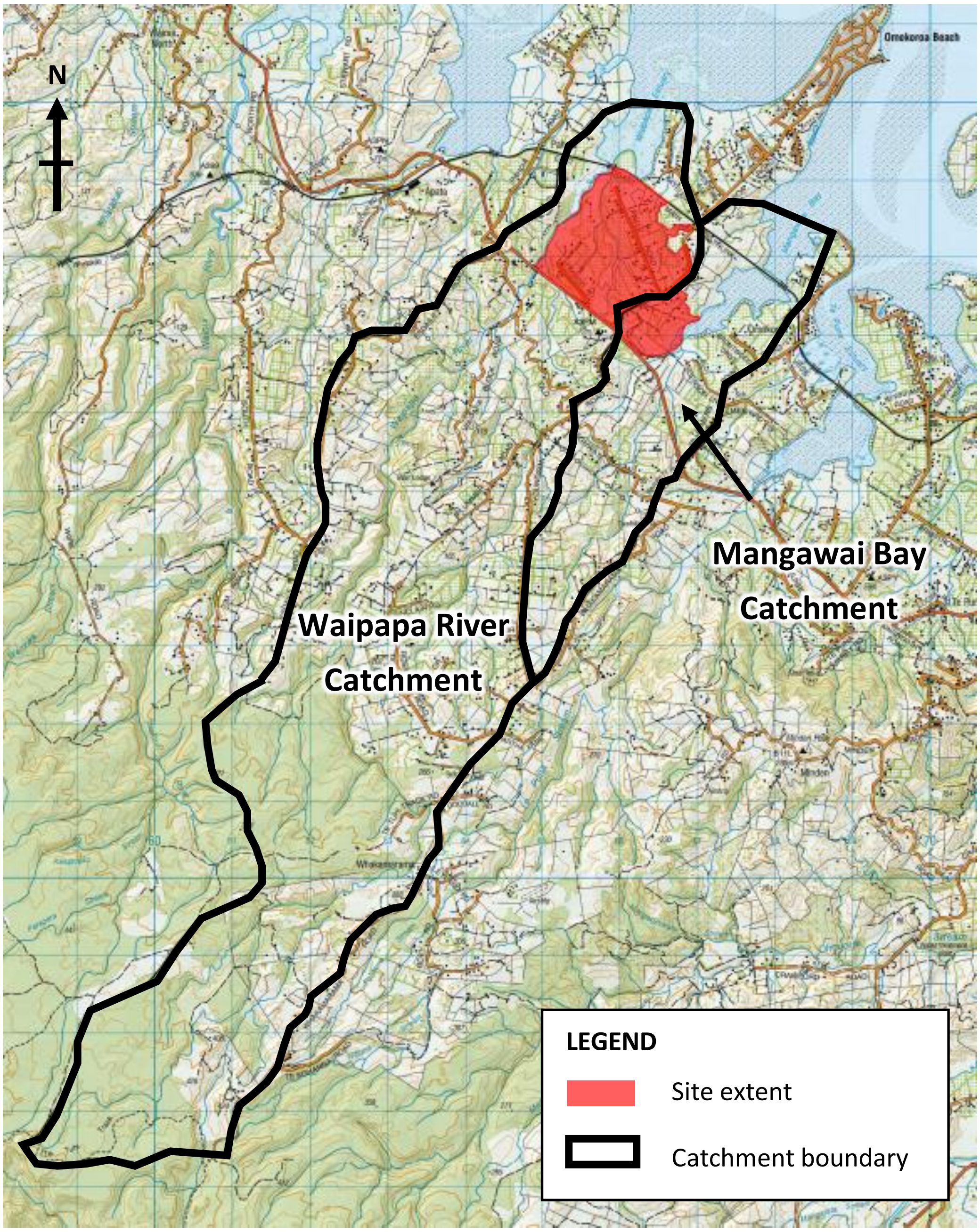


Figure 2-2: Catchment setting (background topographical map sourced from LINZ)

2.2 Topography

The site topography is generally characterised as gently undulating terraces interrupted by incised stream gullies and several knolls that form the top of the subcatchments. Elevations range from 0 m RL adjacent to the harbour, to 75 m RL (relative to Moturiki Vertical Datum (MVD1959)) in the middle of the site. The sides of the stream gullies are steep in places, but the slope angles decrease within the gully floors. Slopes gradients vary from 1V:1H to 1V:3H with the majority of slopes approximately 1V:2H in stream gullies and on the harbour margins.

Away from the stream gullies and harbour margins, the slopes within the site are generally less than 10 degrees. Ground elevations and slope angles for the site (taken from WBOPDC's 2015 LiDAR survey) are shown in Figure 2-3 and Figure 2-4, respectively.

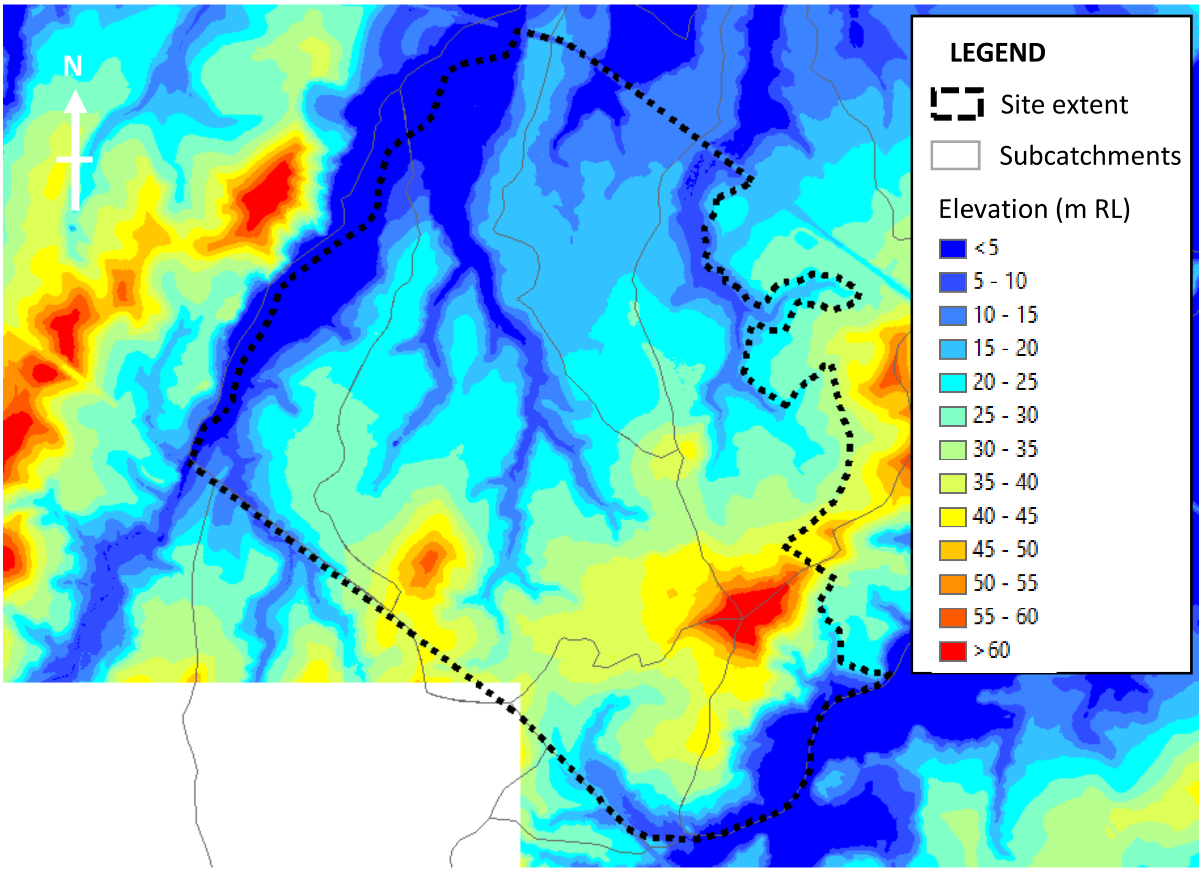


Figure 2-3: Existing site topography - elevation

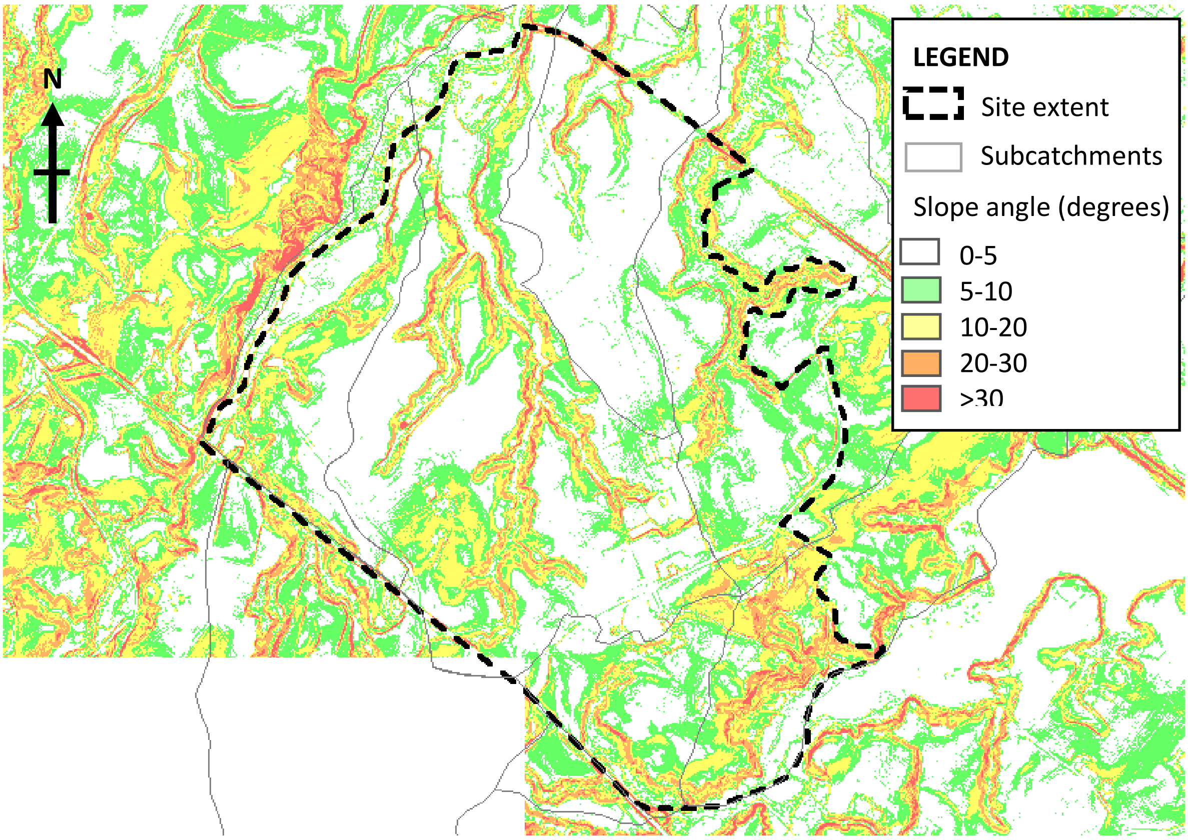


Figure 2-4: Existing site topography – slope angle

2.3 Current landuse

The site is generally rural land used for agriculture, horticulture and lifestyle properties. In the last few years some residential development has begun to occur to the east of the site.

Based on Landcare Research's Land Cover Database version 4 (LCDB4) dated 2012 (i.e. prior to any residential development) orchards comprise almost 50% of the site while pasture comprises approximately 45% of the site (refer Table 2-1). The spatial distribution of the different landuses according to the LCDB4 is shown in Figure 2-5. However, we note that riparian vegetation types observed as part of the streamwalk assessment undertaken by T+T for this study (refer Section 2.7) differ from those shown in LCDB4.

Table 2-1: 2012 landuse breakdown (source: Landcare Research LCD4)

Landuse (P - pervious, I - impervious)	Area (ha)	Percentage of area (%)
Orchard, vineyard or other perennial crop (P)	175.0	48.2
High producing exotic grassland (P)	163.0	44.9
Exotic forest (P)	8.7	2.4
Indigenous forest (P)	6.1	1.7
Herbaceous freshwater vegetation (P)	4.6	1.3
Herbaceous saline vegetation (P)	2.4	0.7
Built-up area (I)	2.4	0.7

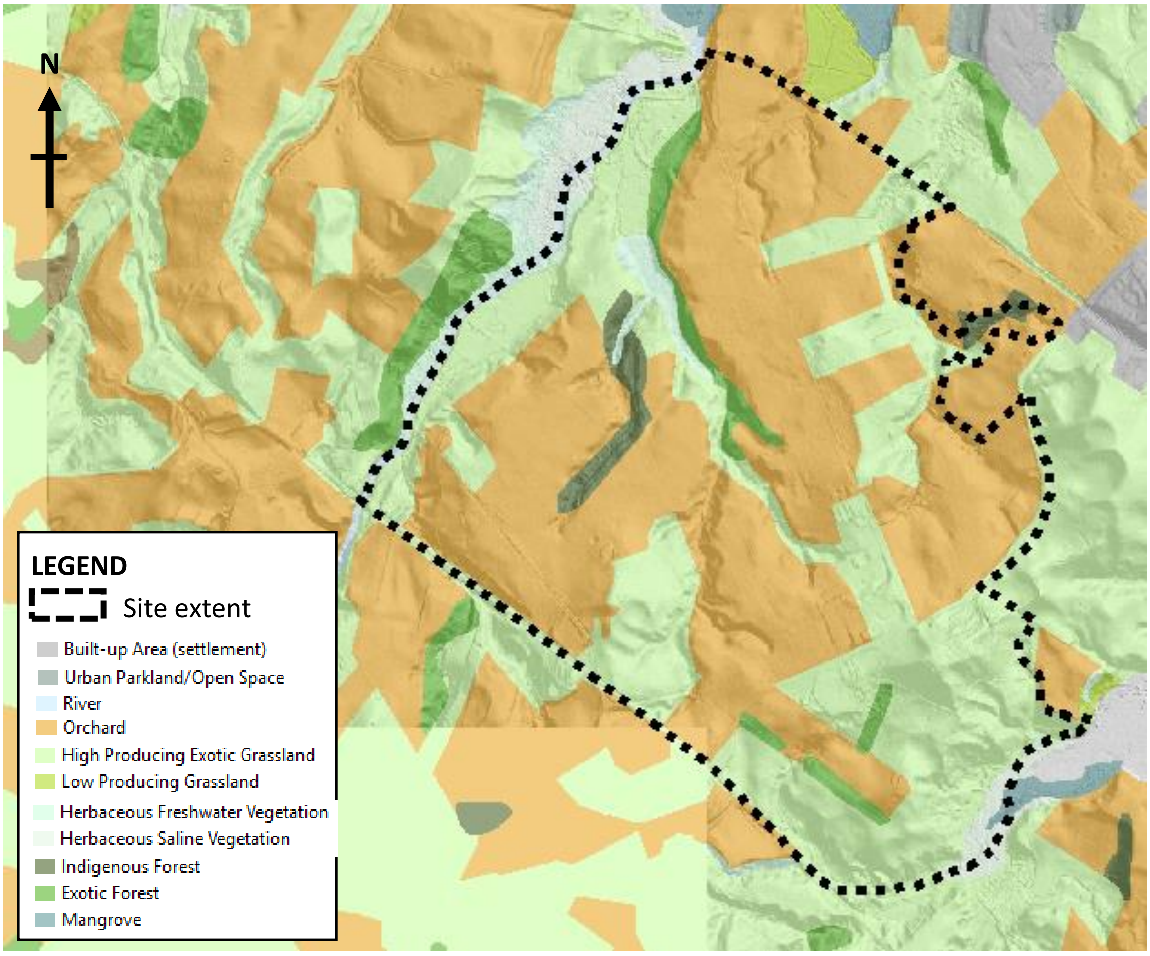


Figure 2-5: 2012 landuse (source: Landcare Research LCDB4)

2.4 Geology and soils

2.4.1 Published geology

Published geology (Briggs et al., 1996) indicates that the site is underlain by three different geological units (refer Figure 2-6). Terrace deposits (tm) of the Matua Subgroup make up the majority of the study area. The Matua Subgroup comprises sands, gravels, lignites, however there is borehole data available for other parts of Omokoroa reasonably close to the site (refer Appendix B for locations). The data collected from these boreholes indicate that the local geology is variable both laterally and vertically but show that that area is mostly underlain by clayey and sandy sediments. This geology is typical of the Tauranga Area.

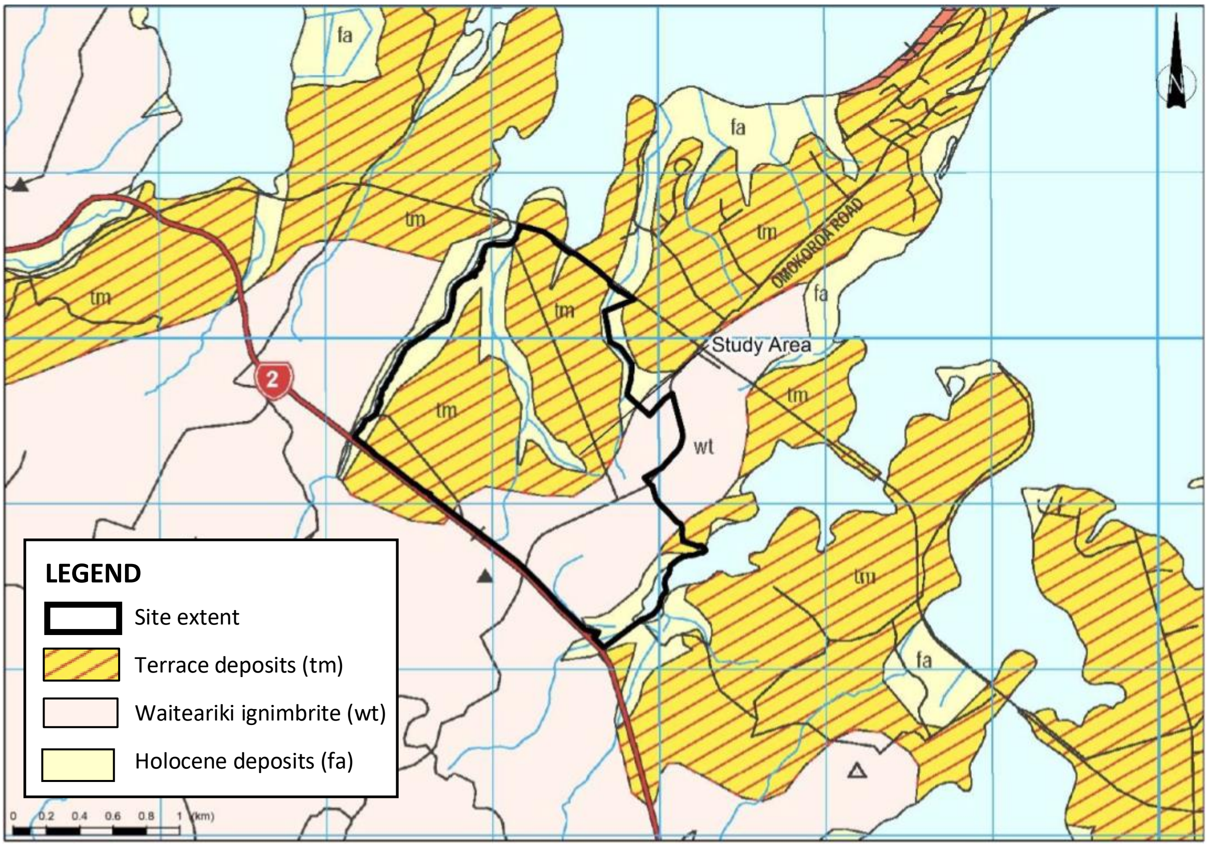


Figure 2-6: Geological map (source: Briggs et al. (1996))

2.4.2 Site walkover

A walkover of the site was conducted by a T+T engineering geologist on 22 November 2019. Exposed soils within the site were limited to shallow failures of superficial soils on slopes adjacent to streams. The locations of these exposures are shown in Appendix B. Exposed soils appeared to comprise landslip debris and alluvium and were primarily sands, but also contained silt and gravel layers.

2.5 Groundwater

There is very little recorded groundwater data within the study area. Results from a series of cone penetration tests (CPT's) undertaken in the south eastern corner of the study area are available in the NZGD. The data collected from these tests show groundwater depth ranging from 3 to 4 m below ground level. The groundwater readings were taken at the time of drilling and were conducted at ground elevations ranging between 43-70 m RL.

In addition to recorded groundwater levels, a conceptual groundwater model has been prepared by T+T as part of a region-wide liquefaction study (T+T, 2019). The model was based on the geomorphology, site observations and established modelling techniques. The groundwater model generally showed groundwater depth is predicted to be <4 mbgl in stream channels and low-lying coastal margins and >4 mbgl on the terraces (i.e. the flatter land where development is proposed).

In addition to the above, some stream banks and soil cuttings exhibited localised dampness and water seepage along geological boundaries. These likely reflect perched water tables where water accumulates above low permeability layers. Such perched water tables have been observed beneath other parts of the Omokoroa Peninsula, most notably along Bramley Drive and Ruamoana Terrace.

2.6 Existing stormwater infrastructure

Currently there is little existing stormwater infrastructure across the site and the predominant conveyance mechanism for stormwater runoff is overland flow into the stream gullies. The major roads within the site (Omokoroa Road, Prole Road and Francis Road) are currently not kerbed and are drained with grassed roadside swales (refer Figure 2-7). Culverts are located where driveways cross the swales.

Figure 2-7: Typical carriageway layouts (Francis Rd pictured top, Omokoroa Road pictured bottom. Sourced from Google Street View)

Within the site there are a number of artificial ponds. These have been created by landowners generally for what appear to be aesthetic purposes. To the north of the site there are also two storage areas that have been formed by the construction of the railway embankment (within subcatchments N1 and N2). There is also a large natural depression near 85 Prole Road that acts as a detention area. The location of these features is shown on Figure 2-8. While these ponds and depressions are not engineered stormwater ponds, they will provide an attenuating function in large rainfall events, as well as some level of water quality treatment. Therefore, they should be preserved and enhanced if possible.

The areas of Stage 3 where residential development has already begun (i.e. just outside of the site extent) are serviced by a traditional stormwater reticulation network and kerbed roads. An engineered stormwater pond has been constructed within subcatchment N2 that provides attenuation, water quality treatment and detention.

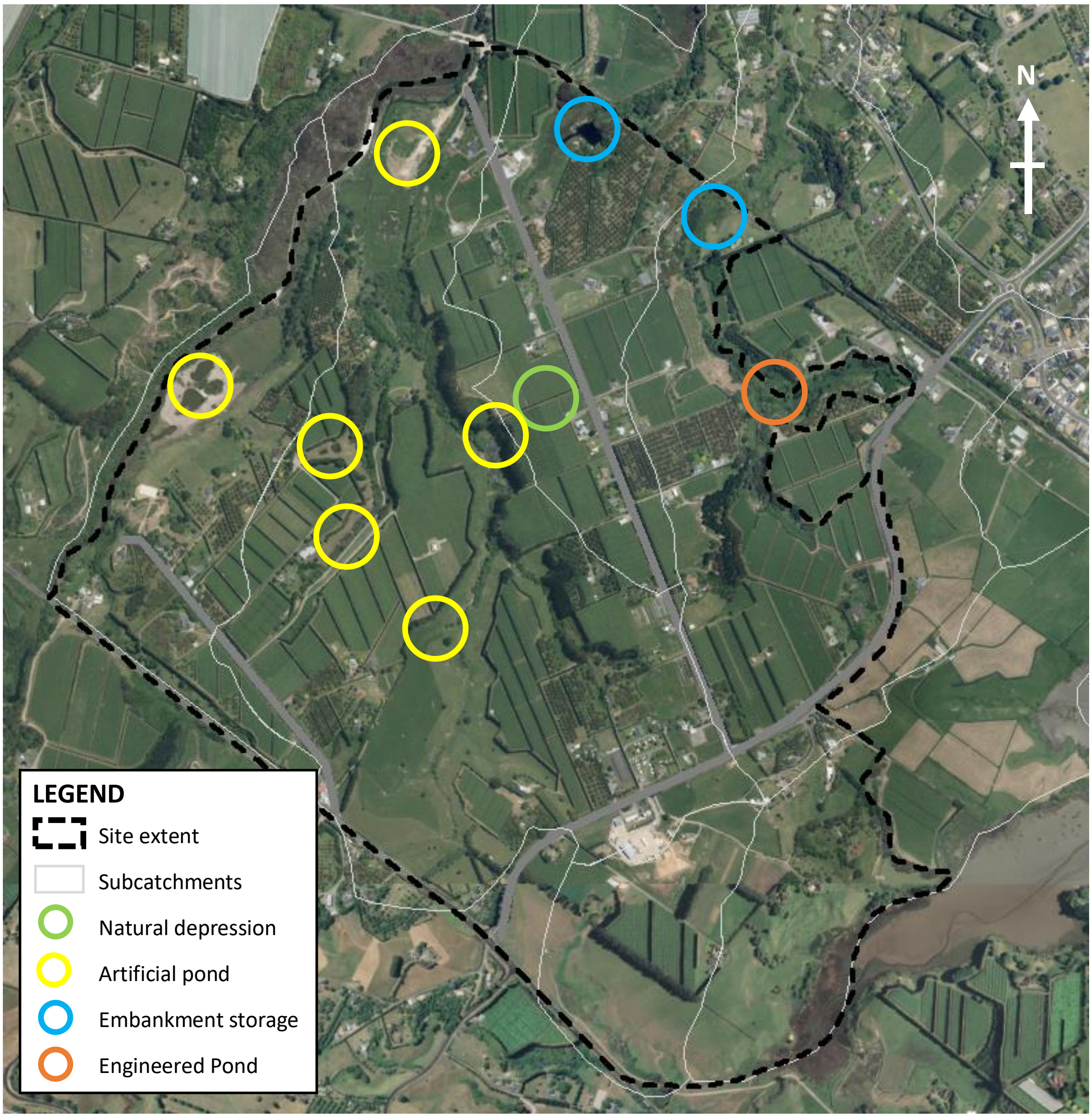


Figure 2-8: Existing ponds, natural depressions and embankment storage areas

2.7 Streams and wetlands

There are a number of streams within the site which play a critical role in conveyance of runoff as well as providing ecological, cultural and amenity value within the site. Without sufficient mitigation, stormwater runoff from impervious surfaces can adversely affect stream health due to increased contaminant and sediment concentrations which can negatively impact instream ecology and water quality. Impervious surfaces can also result in changes in hydrology, namely increased velocity, peak flows and duration of bank-full flows which can lead to stream erosion. Erosion contributes to sedimentation within streams and the downstream marine environment and can result in an adverse effect to instream and intertidal habitat.

All streams were assessed during a two-day site visit on 14 and 15 November 2019 by an ecologist and fluvial geomorphologist. The streams were visually assessed for character, erosion susceptibility and ecological value. This subsection presents a summary of the results of the site assessment. The full assessment results are presented in Appendix C.

The majority of the streams throughout the site have been characterised as 'valley fill' stream types. Valley fills are rare and sensitive stream types linked to erodible geologies/soils. They are often degraded or lost entirely through modified drainage, especially in agricultural (constructed drainage channels) and urban landscapes (increased volume or velocities of peak flows). These stream systems play an important role in regulating flood flows and facilitating surface water and groundwater interactions.

Valley fills generally have discontinuous channels (i.e. no defined channel), are associated with wetland flora, and have possibly formed several ways within the site:

1. When the sediment load exceeds the ability of the channel to carry it. The sediment drops out of suspension and fills the channel and valley floor (hence the term 'valley fill').
2. When indigenous wetland vegetation on the valley floor decreases flow velocities and encourages sediment deposition, promoting more vegetation growth until the valley bottom is filled with both vegetation and sediment.
3. When exotic wetland vegetation (such as willows) invade the valley floor and accelerate the processes described in 2 above.

Valley fill systems require a continuous supply of sediment and low peak flow velocities in order to develop and be maintained. A reduction in sediment or an increase in flow volumes or velocities may promote incision, channelisation, and the subsequent loss of the 'valley fill' morphology (refer Figure 2-9). Once incision occurs, it becomes difficult to reinstate a valley fill morphology, especially if there is a lack of sediment supply.

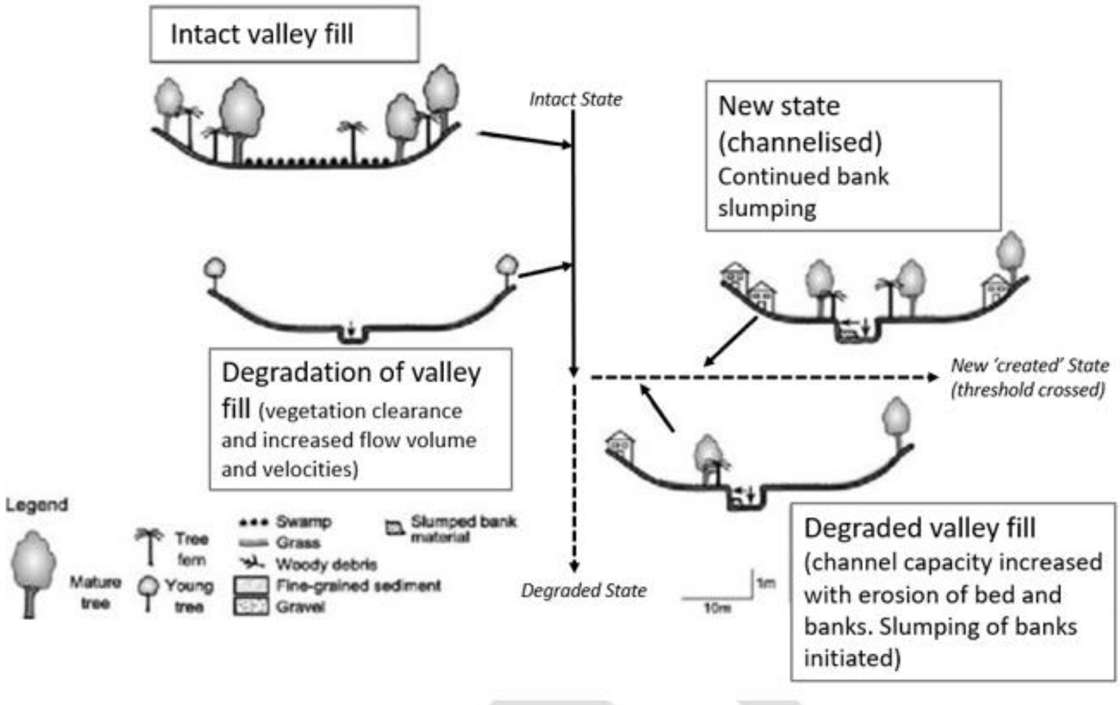


Figure 2-9. Example of the condition trajectory of valley systems (modified from Gregory et al. (2008)

There are still examples of intact valley fills within the site, but many are showing signs of degradation or modification. In some cases, the extensive willow cover is providing a degree of protection from incision. If the willows are to be removed in the future, this process will need to be managed with careful consideration of the stability and integrity of the valley fill systems. This may include staged removal and underplanting of indigenous wetland vegetation.

The downstream end of subcatchment W2 is the only reach assessed in the site to have a 'low sinuosity, straightened, tidal' stream type. This stream type was most likely deepened and straightened to facilitate land drainage for agricultural purposes and consists of two channels (or a single channel that is bifurcated) that extend around the terrace margins. The stream banks of the section of this section of stream are steep (near vertical) and high, however, showed no sign of active erosion, other than bank damage by stock (cattle). This reach is tidal, with vegetation characteristic of saltwater/brackish environments present. An intact valley fill system was observed at the upstream extent of this stream type, and substantial willow root-mats at the interface of the two stream types appear to be the only thing preventing incision of the valley fill system, and saltwater intrusion further upstream.

All streams in the site are spring fed, with permanent springs located at the head of almost all waterways in subcatchments W2 and E1, and intermittent springs located at the head of the waterways in subcatchments E2 and N2. Therefore, stormwater management for the site should aim to maintain the existing surface water and groundwater interactions to prevent these streams from drying up.

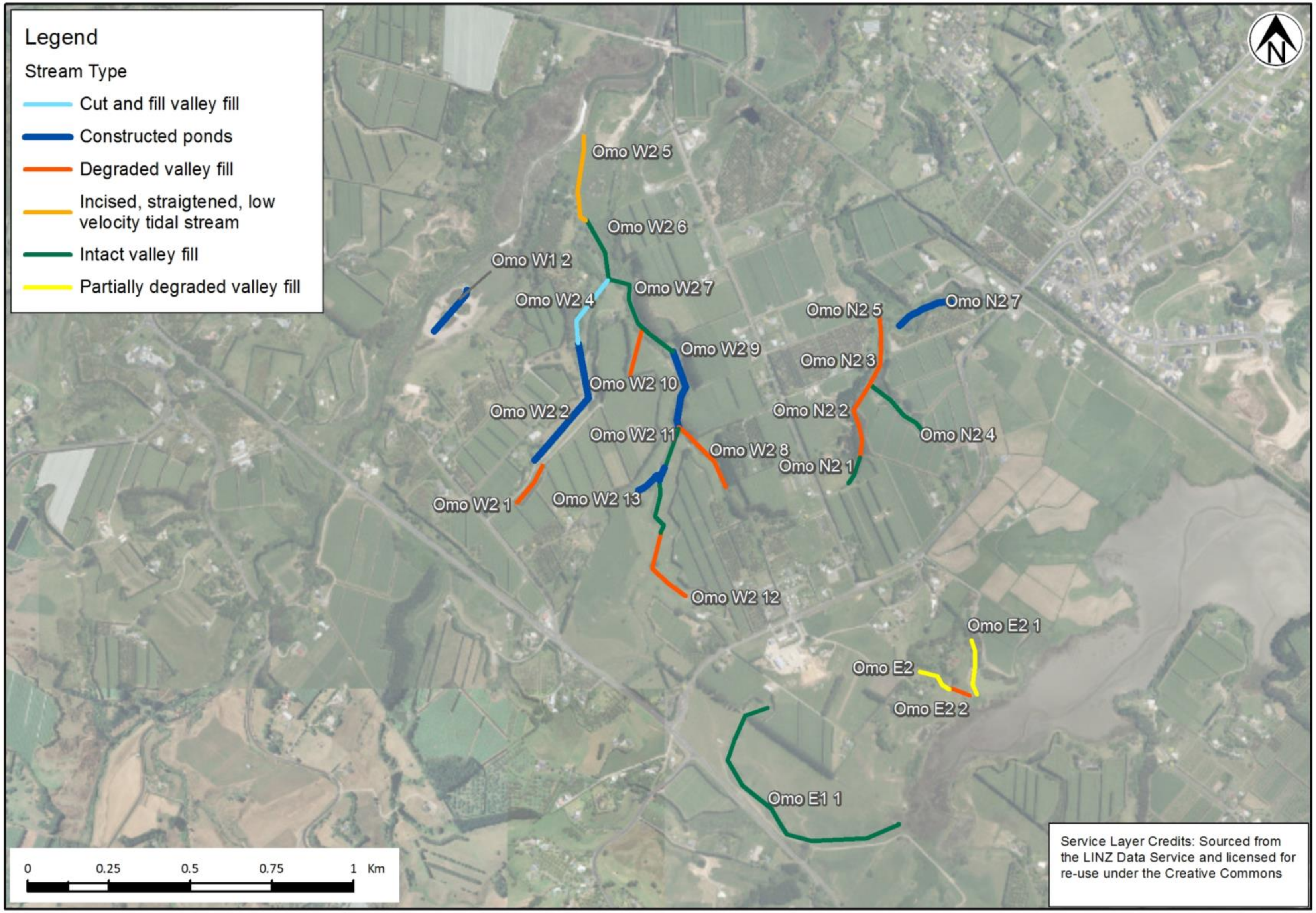


Figure 2-10: Stream types characterised through the site, including the location of constructed ponds.

2.7.1 Erosion susceptibility

An assessment of erosion susceptibility was undertaken on all the stream reaches within the site (except those within subcatchments W1 and N1) based on visual inspection. Erosion susceptibility was scored for each reach based on several factors (such as channel slope, bank slope, observed erosion, channel modification and riparian vegetation), with weightings applied to each parameter depending on its importance in determining erosion potential. The assessment methodology used for this study is fully described in Appendix C. Based on this assessment method, 35% of the reaches through the site have been identified as having high erosion susceptibility of both their bed and banks, 50% of the reaches through the site have moderate erosion susceptibility of their banks only, while 60% have moderate erosion susceptibility of their bed only. Only 10% of the reaches (two reaches) assessed are considered to have low bank erosion susceptibility. Both of the reaches are low slope environments, with low flows and have extensive woody vegetation protecting their banks. The erosion susceptibility of all reaches was elevated largely due to the unconsolidated and fine-grained nature of the bed and banks, steep sloped banks, bank shape, and evidence of erosion already occurring.

Reach Omo_E2 had the highest overall erosion susceptibility score of all reaches and has been classified as a degraded valley fill, meaning the stream type appears to be moving from a wide shallow channel to a narrow, defined and incised channel (refer Figure 2-11). The high erosion susceptibility rating was largely due to the steep nature of its banks, evidence of bed and bank erosion already occurring, culverts in the stream bed channelising flow, stock access reducing bank stability and a lack of woody riparian vegetation.

Given the reasonably high erosion susceptibility of these streams, stormwater management for the site should aim to minimise changes to site hydrology (runoff volumes and velocities).

Figure 2-11: Reach Omo_E2 which has the highest erosion susceptibility. Note the steep slope, confined valley floor, access for stock, culvert, and evidence of bank erosion already occurring

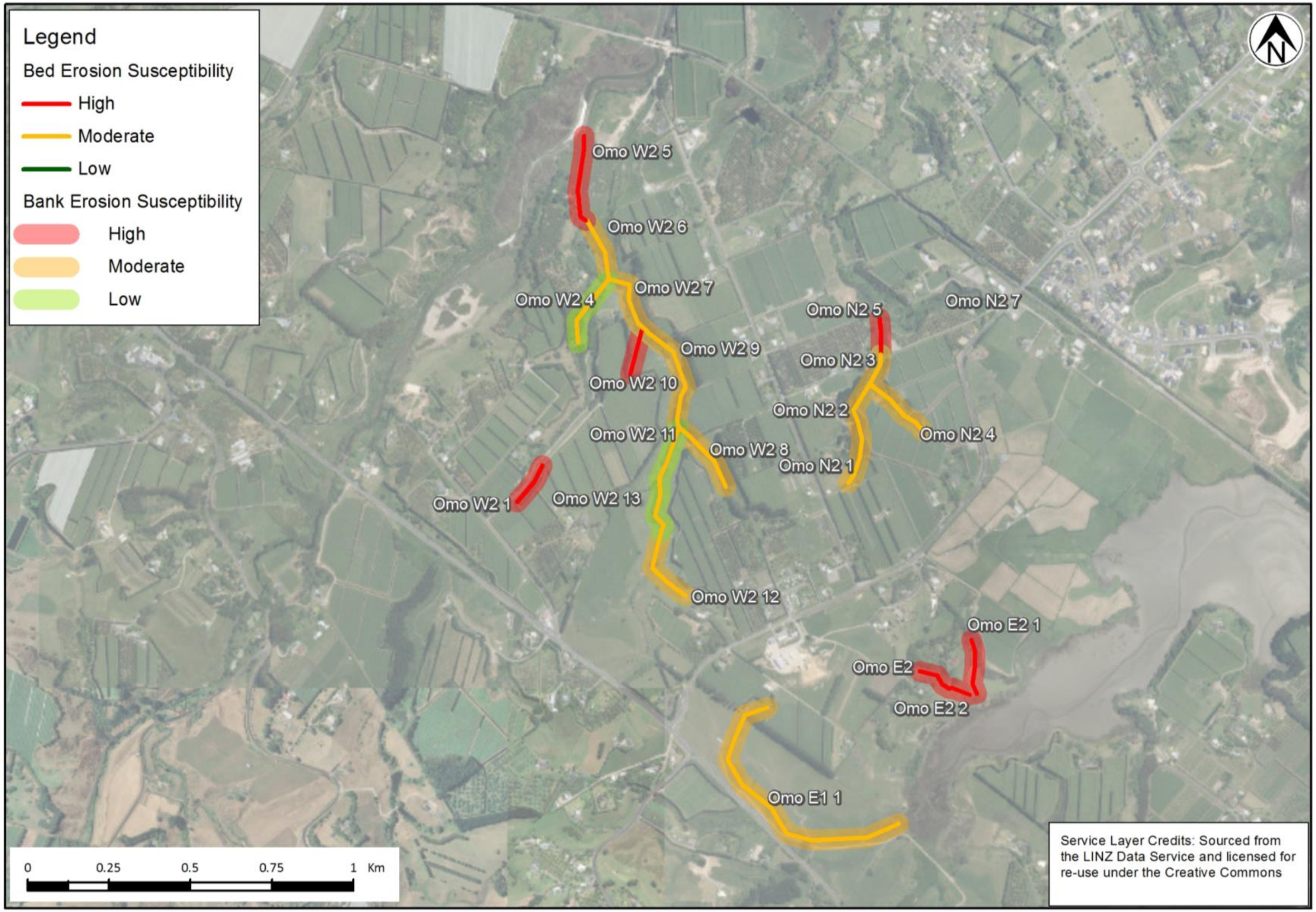


Figure 2-12: Erosion susceptibility scores for the banks (thick lines) and the bed (thin lines) for the project area

2.7.2 Ecological values

In-stream habitat and ecological value was assessed using the Rapid Habitat Assessment (RHA) (Clapcott *et al.,* 2015). The RHA scores habitat on a number of parameters, with the total score providing a condition ranking for habitat. For purposes of this report, scores between 0 and 30 are considered poor habitat with low ecological value, scores between 31 and 39 are considered moderate habitat with moderate ecological value, and scores between 40 and 70 are considered high habitat with high ecological value. Figure 2-14 shows the habitat classification for each reach that was assessed. The potential for other ecological functions outside of general habitat (such as spawning, and detritus sorting) and water quality parameters (which may impact on habitat value or ecological function) were also considered.

All stream types within the site were characterised as 'soft bedded streams' in the RHA, and first order streams which had wetland character. For the purposes of this report, streams within a wetland were classified and assessed as 'streams' and the RHA applied.

No fish were observed during the site assessment, however records from the New Zealand Freshwater Fish Database (NZFFDB, 2019) suggest some indigenous species may be present within the site (such as Longfin eel, Shortfin eel, Torrent fish, Banded Kokopu, Inanga, Common Bully, Giant Bully and Redfin Bully). However, seven partial fish barriers were identified on five reaches by T+T during the walkover, mostly within the mid-reaches of Omo_N2, Omo_W2 and Omo_E2. These barriers may be limiting the number, distribution and diversity of indigenous fish throughout the site, especially in the upstream or headwater reaches, where suitable fish habitat exists. These fish barriers could be removed as part of any enhancement of the stream corridors.

Overall, the in-stream habitat and ecological value of all reaches throughout the site was generally assessed as being Moderate (averaged RHA score of 38). Modifications of the headwater areas of all reaches have altered ecological character, through damming, bank modification, vegetation clearance, and livestock damage. However, some headwater reaches have been fenced and planted with indigenous riparian vegetation (such as Omo_W2). Where this has occurred, these reaches have the potential for significant ecological condition improvement over time.

The streams and wetland habitat vary from poor habitat with low ecological values in Omo_W2_1, Omo_W2_2, Omo W2_12 and Omo W2_13 (average RHA score of 24) to high habitat with high ecological values in Omo_W2_4, Omo_W2_8, Omo_W2_9 and Omo_W2_11 (average RHA score of 45). The lower reaches of all subcatchments (specifically Omo_W1_1 and Omo_W2_6 and Omo_W2_7) also have high ecological value at the interface with estuaries, due to the presence of native fish spawning habitat, fewer human development/disturbance impacts, and a higher proportion of indigenous plant species. Mid-reaches and lower reaches (Omo_E1_1, Omo_E1_2, Omo_E1_1, Omo_W2_4, Omo_W2_6, Omo_W2_7, Omo_W2_8, Omo_W2_9, Omo_W2_11) have higher values owing to more varied instream habitat, more vegetation canopy coverage, more intact riparian margins, and fewer fish passage restrictions. Spot water quality testing undertaken by T+T during the walkover suggested low nutrient inputs, with low dissolved oxygen levels in the ponded areas.

Some reaches in subcatchment Omo_N2 appear to have been modified as part of recent development of the Kaimai Views subdivision, namely Omo_N2_5 and Omo_N2_7 (refer Figure 2-13). Due to the modification Omo_N2_5 and Omo_N2_7 are now considered to have poor habitat and low ecological value, largely because earthworks and damming has removed hydraulic diversity, removed riparian margins (resulting in low shade and low in-stream organic matter), low filtering capabilities and no provision for fish passage. Spot water quality testing undertaken by T+T during the walkover showed elevated levels of nutrients which can increase the risk of increased algal and macrophyte growth.

Figure 2-13: Omo_N2_5 and Omo_N2_7 have been modified during development and have been assessed as having poor habitat and low ecological value

Both reaches within subcatchment E1 have high ecological values with good potential galaxiid spawning habitat and good riparian margins. The presence of fernbird (*Bowdleria punctata vealeae* – with a status of At Risk – Declining) (Robertson *et al.,* 2017) was also noted at the interface with the estuary within scrub and rushes suggesting this reach provides valuable habitat for wetland birds, potentially including other at risk or threatened species. Therefore, it is recommended that these reaches not be used in the storage or treatment of stormwater to reduce the risk of potential ecological impacts.

Subcatchment W1 includes a small reach of the Waipapa River, the floodplain ponds of the Waipapa River, as well as a modified watercourse. The river itself was assessed by T+T from the walkover as having high habitat and ecological value. The river provides potential fish spawning habitat due to the relatively intact riparian margins and tidal influence. Further downstream (near the confluence with Omo_W2_5), habitat values are even higher with a scrub-marsh complex present. The floodplain ponds (Omo_W1_2) scored low for habitat values as they are limited in habitat, being largely open water with little riparian vegetation and macrophyte growth. The floodplain ponds have fish passage as a floodgate remains permanently open to the river. The modified watercourse (Omo_W1_3) was likely once a stream, however it has been channelised, straightened, widened and dredged.

Stormwater management for the site should aim to mitigate adverse effects on the spawning habitat within subcatchments W2 and E1, and along the Waipapa River. Indigenous fish spawning habitat is sensitive to excessive sedimentation and increases in flow velocity, and therefore is often at risk of being lost during, and as a consequence of, urban development.

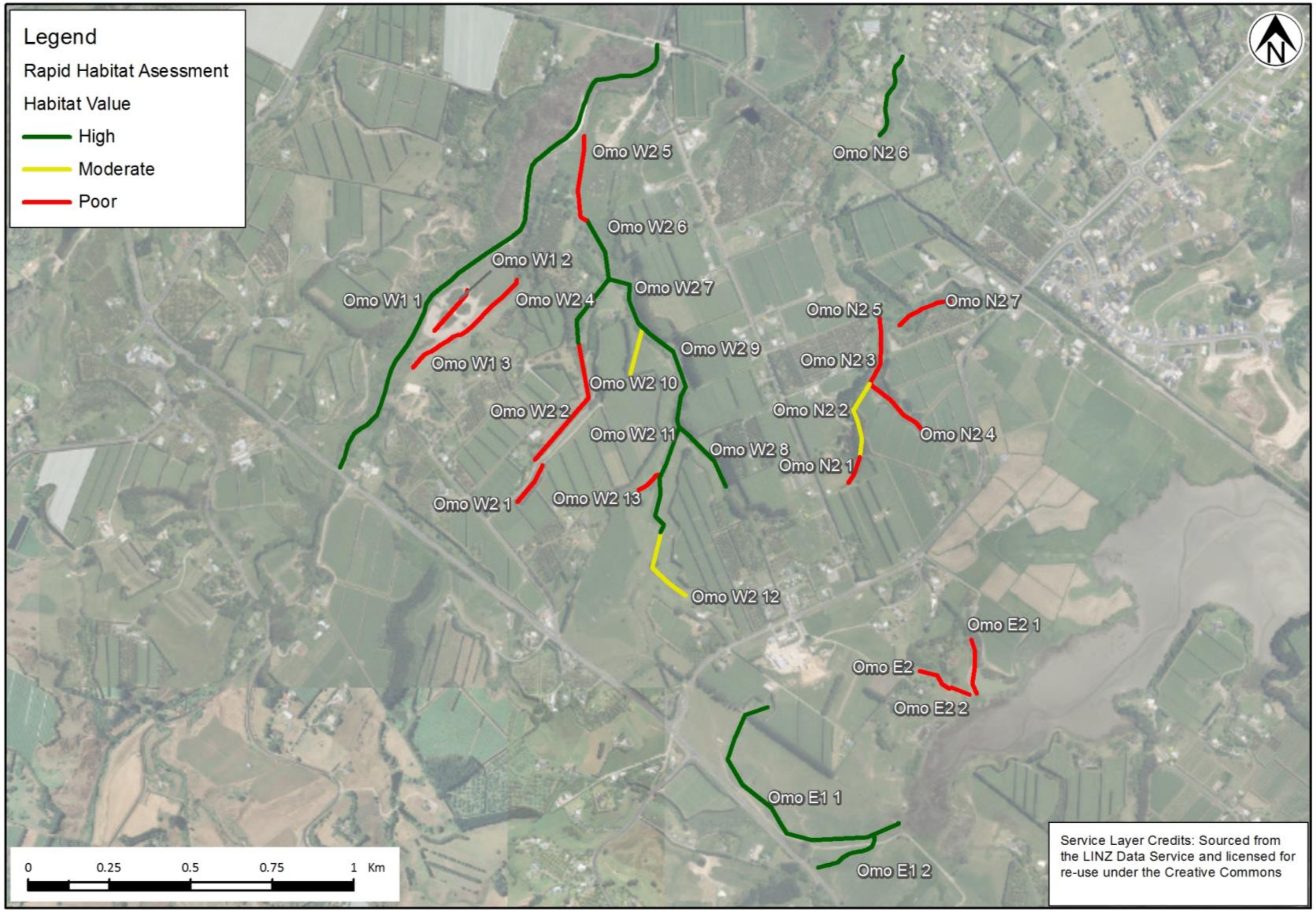


Figure 2-14: Habitat Value classification for all reaches throughout the site as determined from the Rapid Habitat Assessment scores

2.8 Natural hazards

2.8.1 Rainfall induced flooding

In 2017 WBOPDC commissioned the build of a stormwater network model for the Omokoroa Peninsula. This model was a 1D model with overland flow paths included in the 1D layout. In 2018, Beca created a 2D model as part of the 2017 addendum to the Omokoroa SMP. This model had no pipe network included and was intended to be used only for planning purposes. Since these models were constructed, there have been a lot of landuse changes resulting in hydrological changes in Omokoroa. In December 2018 WBOPDC commissioned Beca to combine the 1D and 2D models and include recent changes in landuse. The 100 year enveloped[1] flood extent is shown in Figure 2-15 below.

The combined 1D/2D model is a rain on grid model built using ICM Version 9.0. The model surface was built using LiDAR flown in 2010 which was then converted to a triangulated mesh. The hydrological routing model for the Omokoroa Stormwater model was developed following the methodology set out in the WBOPDC 2014 modelling guidelines with losses based on the Soil Conservation Service (SCS) curve number method. The landuse modelled within the site is based on the proposed structure plan zoning. The rainfall events were produced using NIWA's High Intensity Rainfall System (HIRDS) V4 to generate a 24-hour nested storm hyetograph with climate change to 2100 (RCP 8.5). Boundary conditions for the model are based on climate change adjusted storm tide levels from NIWA's coastal inundation modelling for Tauranga Harbour. For full details on the Omokoroa flood model the reader is referred to Beca's report 'Omokoroa Stormwater Model – Model Build Update and System Performance Report' dated 31 July 2019.

The flood model results show that in a 100 year event there are a number of areas where the 100 year flood depths are predicted to exceed 0.1 m in depth within the future urban areas. It should be noted that this model was run with existing (i.e. pre-developed) topography. The majority of the flooding within future urban areas is less than 0.5 m deep. The exception to this is the depression near 85 Prole Road where the predicted flood depth exceeds 1 m. The golf course downstream of the site (subcatchment N2) is known to currently experience flooding. A natural hazard risk assessment by T+T was underway at the time of writing this report which includes rainfall-induced flooding for Stage 3 of Omokoroa.

[1] The maximum flood extent resulting from rainfall and storm tide combinations with a joint probability of a 100 year ARI

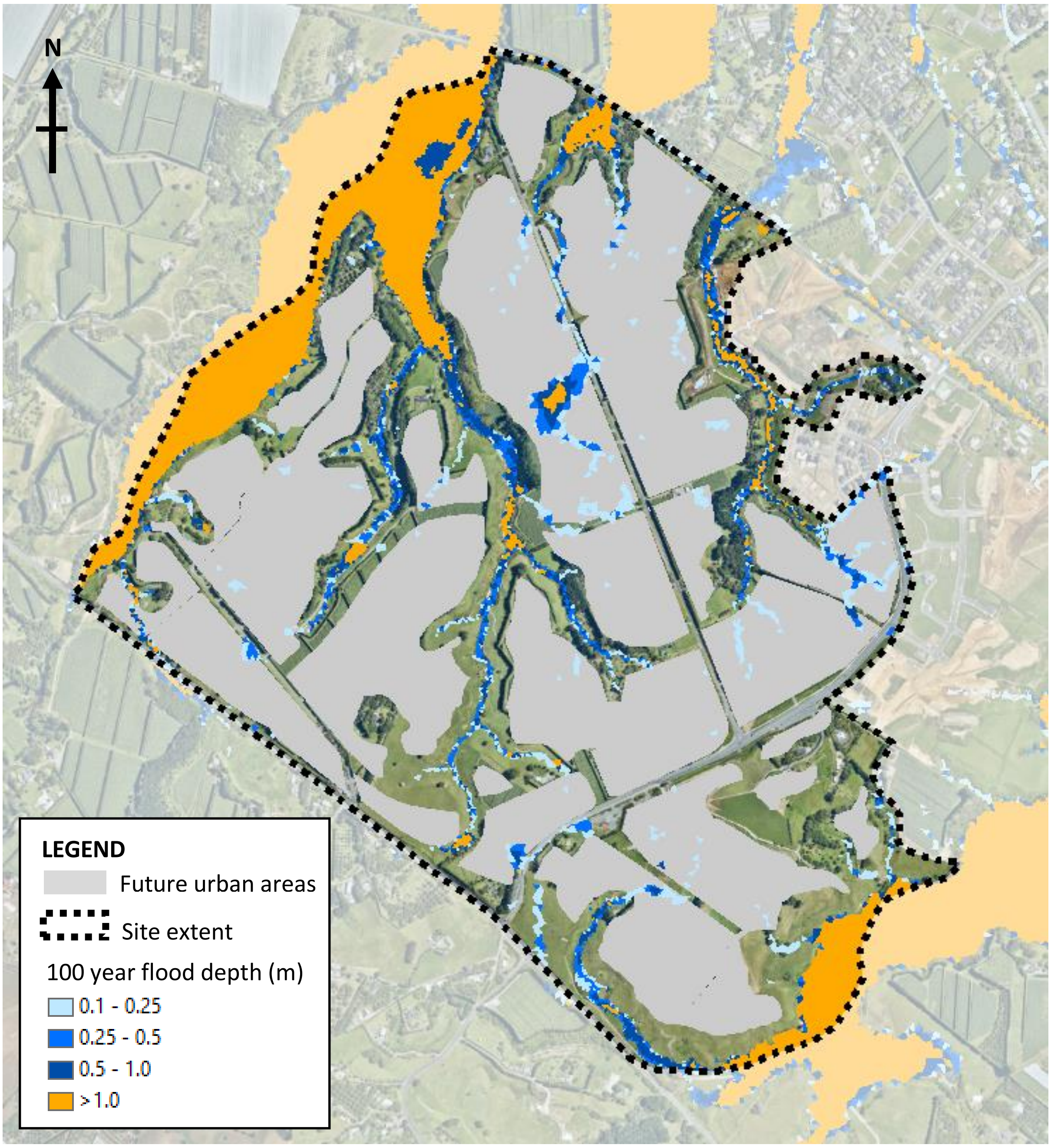


Figure 2-15: Flood model results (100 year ARI)

2.8.2 Slope instability

Omokoroa has been affected by significant landsliding in recent years. This landsliding has primarily been associated with the tall and steep slopes, and coastal cliffs to the north of the Stage 3 area (e.g. Beach Grove, Bramley Drive, Harbour View Road, Kowai Grove, McDonnell Street, Ruamoana Terrace and Waterview Terrace during ex-Cyclone Debbie (March/April 2017)). These landslides were either deep seated failures involving large blocks of soil, or superficial, comprising surface soils and vegetation.

The large, block-type failures are often associated with a build-up of groundwater pressure and layers of sensitive soil (e.g. Pahoia Tephra). The superficial failures are likely caused by surface wetting of the soils due to heavy rainfall. The slopes that failed were also often affected by erosion at their toes caused by wave action from the harbour (Kluger et al., 2019).

No recent, large-scale landslides were observed within Stage 3 during the T+T walkover and the slopes in Stage 3 appear to have been largely unaffected by ex-cyclones Debbie and Cook. However, we did observe some small-scale slope failures and signs of slope creep (slow downward movement of surface soils). In addition to this, the slopes adjacent to the streams and harbour margin are locally high and steep. These features coupled with possible perched water tables suggest that some slopes may be vulnerable to instability under certain conditions.

3 Summary of site-specific constraints and opportunities

Based on the site characteristics, as described in Section 2 above, a number of constraints and opportunities for stormwater management have been identified. These are summarised in Table 3-1.

Table 3-1: Summary of constraints and opportunities

Constraints
• The stream corridors play an important role in stormwater conveyance, flood storage, amenity and ecological habitat and should be preserved and enhanced to the extent practicable. • Slope instability risk may preclude the use of infiltration and bioretention devices in some areas (unless lined). • Existing flooding issues in the golf course downstream of the site (subcatchment N2).
Opportunities
• The structure plan area is predominantly a greenfield area which provides an opportunity to incorporate WSD to maintain pre-development hydrology and consider alternative approaches such as the use of overland flow channels instead of pipe networks for primary flows. • The site is predominantly relatively flat outside of the stream gully corridors. This is conducive to the use of devices such as swales. • There are currently a number of existing ponds/storage areas that can be utilised for stormwater management. • The site contains a number of streams and wetlands with high ecological values. These could be enhanced to regulate stream flows and enhance ecological functions. • There are a number of subcatchments within the site that discharge directly to the Tauranga Harbour. This reduces the need to manage stormwater quantity in these areas where stream erosion is not a concern. • Other than the known flooding issues within the golf course, there are no other known downstream flood risks. • Providing opportunity for on-site infiltration to improve aquifer recharge and stream baseflows. • Removal/modification of artificial fish passage barriers to improve the ability of migrant fish species to access upstream habitat. • The change in landuse from rural land to urban is an opportunity to revert to natural sedimentation loading in freshwater systems and in the harbour if sediment loads during earthworks are carefully managed.

4 Current stormwater management approach and requirements

4.1 Omokoroa SMP recommendations

The Omokoroa SMP (including the 2017 addendum) identifies the following key issues and considerations for stormwater management in Omokoroa:

- The need to improve the quality of stormwater discharged to the Tauranga Harbour.
- Slope instability risk including the potential for instability to be exacerbated by stormwater infiltration.
- Impervious areas having an adverse effect on stream health and ecological values (including erosive effects).
- The opportunity for enhancement of the existing stream corridors.

The Omokoroa SMP recommends a mix of a conventional drainage system (i.e. pipe, kerb and channel) and a WSD approach (e.g. swales for conveyance instead of pipes) with WSD being the preference in flat areas and areas with lower development densities. The SMP recommends "full capacity" ponds (i.e. sized to provide the stormwater management requirements for the entire subcatchment) as a robust "backup" to any areas where WSD might be used. Therefore regardless of which conveyance approach was adopted, all runoff would be conveyed to a stormwater pond which would provide water quality treatment, flood attenuation and detention of smaller events to address stream erosion risk. In total 17 new stormwater ponds and enhancement of one existing pond are recommended within Stage 3 of Omokoroa. Other recommendations made in the SMP are as follows:

- Recognise and enhance the natural drainage patterns of the peninsula, preserving natural streams where possible or appropriate, and providing reserve corridors.
- Protection of secondary overland flowpaths as a part of site planning.
- Encourage measures to reduce volume of stormwater runoff using measures including:
  - Onsite management of disposal of stormwater using infiltration where appropriate.
  - Minimising impervious area and retaining natural flood retention areas.
  - Storage and reuse of stormwater runoff where appropriate.
  - Retention or creation of non-structural stormwater controls.
- Use management measures to minimise the contamination of stormwater runoff including:
  - At source management of contaminants.
  - Use of best practicable options to reduce levels of contaminants entering surface water bodies.
  - Treatment of stormwater prior to discharge to receiving environments where appropriate.
  - Prevention of inappropriate discharges of contaminants to stormwater systems (such as discharges that should be directed to trade waste) such as appropriate site management and appropriate disposal of wastes.
- The use of management devices such as stormwater ponds, dry detention basins and swales.
- Consideration should be given to achieving effective stormwater management within individual developments through the use of low impact design techniques.
- Use of soakpits minimised and not used in steeper areas or where there are soils sensitive to instability.

4.2 Omokoroa Comprehensive Stormwater Consent (CSC) requirements

WBOPDC has obtained a CSC for Omokoroa based on the Omokoroa SMP. The Omokoroa CSC sets out the consent conditions for how stormwater shall be managed in Omokoroa. The Omokoroa CSC was granted by Bay of Plenty District Council (BoPRC) on 14 July 2003 and amended by the Environment Court in 2004. The relevant conditions for stormwater management are summarised below:

- Condition 5.1 - Works pursuant to this consent shall be carried out in general accordance with the *Omokoroa Peninsula Stormwater Management Plan* Revision 3 July 2002 and shall be generally located in accordance with Figure 6.2 of the *Omokoroa Peninsula Stormwater Management Plan* Revision 3 July 2002.
- Condition 5.9 - The consent holder shall ensure that any changes to activities authorised by this consent and detailed in the *Omokoroa Peninsula Stormwater Management Plan* Revision 3 July 2002 shall be minor in nature and shall not alter the character or increase the scale or intensity of any actual or potential adverse effects of those activities on the received environment.
- Condition 6.1 - The consent holder shall ensure that:
  - The use of soakholes is minimised; and
  - Discharges are directed to defined water courses and not over or onto steep slopes; and
  - Wherever practicable, stormwater overflows from pipes, drains or swales be directed through defined overland flow paths; and
  - Discharges of road run-off occur at frequent intervals to reduce concentration of flow.
- Condition 6.3 - The consent holder shall ensure that the design and construction of stormwater systems pursuant to this consent shall meet the following criteria:
  - A 100 year return period flood for stormwater systems to protect major communal facilities related to telecommunications, electricity and water and sewage disposal systems and bridges.
  - A 50 year return period flood for stormwater systems to protect residential property, commercial and industrial buildings.
  - A 10 year return period flood for stormwater systems to protect important recreational fields, and streets without alternative access.
  - A minimum 5 year return period flood for any primary (piped) stormwater system.
- Condition 6.4 - The consent holder shall, wherever practicable, minimise the area of impervious surface area contributing to stormwater runoff.
- Condition 6.5 - The consent holder shall, wherever practicable, utilise swales and other low impact design measures to reduce the rate and volume of stormwater runoff.
- Condition 6.6 - The consent holder shall, wherever practicable, construct ponds at discharge points to streams or the harbour, to attenuate flood peaks.
- Condition 6.7 - The consent holder shall, wherever practicable, enhance watercourses with riparian planting.
- Condition 6.9 - The consent holder shall manage the stormwater system such that the activities authorised by this consent do not result in significant adverse effects on aquatic ecosystems.

- Condition 7.2 - The consent holder shall take all practicable measures to prevent the discharge of any toxic substance that may be harmful to any form of aquatic life, via the stormwater system.
- Condition 8.2 - The consent holder, shall design and construct stormwater treatment devices authorised pursuant to this consent, to remove as a minimum 75 percent of suspended sediment on a 10 year average basis.

5 Cost of water sensitive design vs conventional development

One of the key barriers to the implementation of WSD in New Zealand is the perception that it will cost more than conventional stormwater management. Much research has been undertaken to understand the difference in life cycle costs between the two approaches in the last few decades. This has included both case studies of incurred costs for completed developments as well as using life cycle cost (LCC) modelling to compare the lifecycle costs (i.e. design, construction, operation and maintenance etc.) of WSD against conventional stormwater management. This section presents the findings from some recent literature reviews undertaken by New Zealand researchers on this topic.

Ira et al. (2015) undertook an international literature review of comparative case studies to determine if it was possible to quantify the cost differential between WSD and conventional developments. Ira et al. (2015) reviewed approximately 41 reports/papers that covered 4 countries and 53 case studies. The majority of available cost information from actual case studies related to design and construction costs only (total acquisition costs). A summary of the cost differentials found in the literature is summarised in Figure 5-1 below, with a negative differential indicating that WSD has a higher cost than conventional development.

Case Study Locality	WSUD Type	Objectives for WSD	Percentage Difference (Ave)	Cost Type
Australia	Rain tanks, rain gardens, detention basin	Water savings/ Flood storage	-55.5%	LCC
Australia	Rain tanks, rain gardens, detention basin	Water savings/ Flood storage	-27.7%	TAC
New Zealand	Rain gardens, swales, ponds/ wetlands	Treatment/ Attenuation	-13.5%	TAC
New Zealand	Rain gardens, swales, ponds/ wetlands	Treatment/ Attenuation	7 - 15x greater	MC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-9.6%	TAC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-26.8%	MC
New Zealand (theoretical modelling - UP)	Rain gardens, porous pavement, gravel storage	Treatment	-11.0%	LCC
United Kingdom	Open storage	Reduce WW overflows	15.0%	TAC
United Kingdom	Open storage	Reduce WW overflows	-23.0%	MC
USA	Rain gardens, swales, porous paving, wetlands	Treatment, attenuation, reducing WW overflows	23.0%	TAC
USA	Rain gardens, bush trees, swales, green roof, wetlands	Treatment, attenuation, reducing WW overflows	24.0%	LCC
INTERNATIONAL AVERAGE*			**-2.6%**	**TAC**
INTERNATIONAL AVERAGE*			**-24.9%**	**MC**
INTERNATIONAL AVERAGE*			**-15.7%**	**LCC**

*Average derived from 53 case studies across 4 countries

Figure 5-1: Summary of cost differentials from international and national literature (Ira et al., 2015)

The Australasian case studies within the wider international case studies tended to indicate increased costs associated with WSD, namely:

- Total acquisition costs (TAC) of WSD 16.9% higher than conventional.
- Maintenance costs of WSD 26.8% higher than conventional.
- Life cycle costs of WSD 33.2% higher than conventional.

NZ’s most detailed WSD case study (Long Bay) estimated a 12% increase in TAC on a per lot basis for the WSD scenario.

The literature review showed a clear difference between case studies from the UK and USA and those from Australia and NZ. Many of the studies from the USA and UK showed large cost savings associated with WSD. However, these are often compared against the cost of separating large scale combined wastewater systems as reducing combined sewer overflows is often the primary driver for implementation of WSD in these countries. Also, the cost savings reported in these studies is often related to the “avoided costs” of site earthworking, preparation, concreting and reduced piping rather than the costs of the stormwater management devices themselves.

The literature review highlighted the difficulty in quantifying a cost differential between WSD and conventional stormwater management due to the high number of variables for each specific case study. These variables include catchment size, proportion of impervious area, device types and the jurisdiction in which the site is located.

Ira et al. (2015) also undertook some life cycle cost modelling using COSTnz assuming a life cycle analysis period and life span of 50 years for a range of different scenarios. The results of the 75% TSS removal scenario is shown in Figure 5-2. The results show that more decentralised management approaches (swales, raingardens etc.) generally have higher lifecycle costs than end of pipe solutions (ponds and wetlands), with a greater cost difference with increasing levels of imperviousness. Ira et al. (2015) concluded that on average a WSD approach (using raingardens, swales, infiltration and wetlands) is 59% – 70% more expensive than an end of pipe solution (NPV lifecycle costs). These costs are reasonably comparable to the majority of studies undertaken in Australia, which suggests an average 55% increase in costs with WSD compared to conventional.

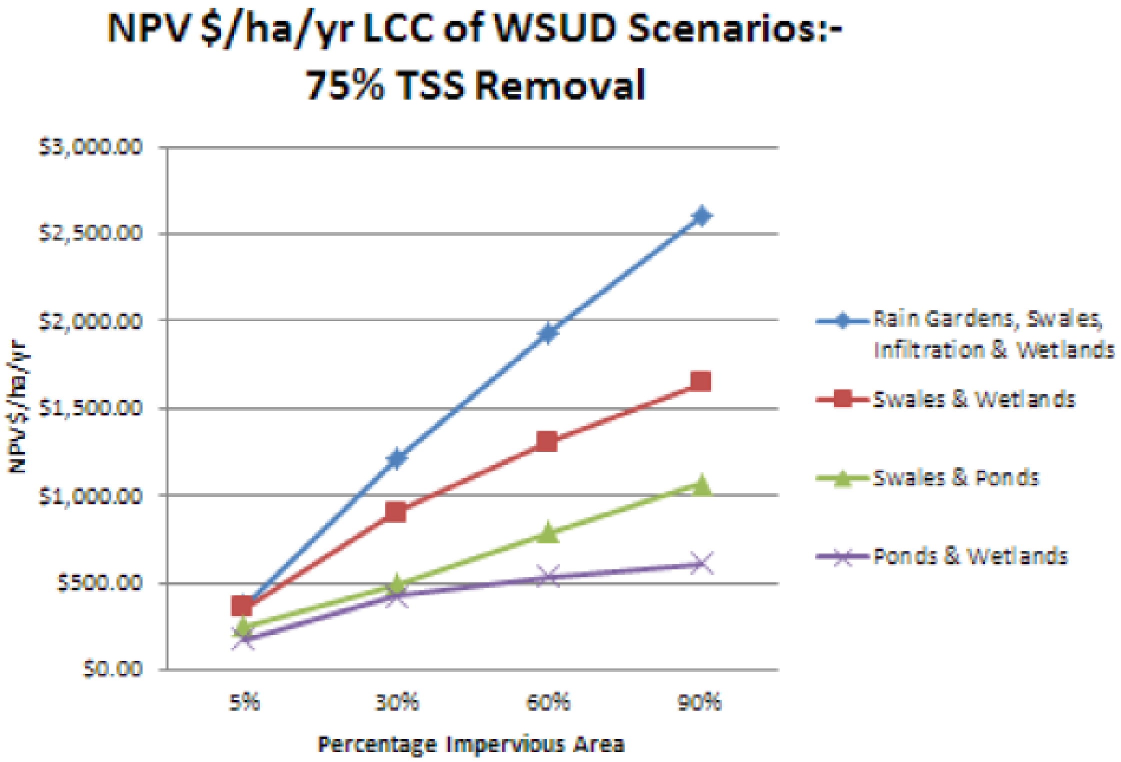
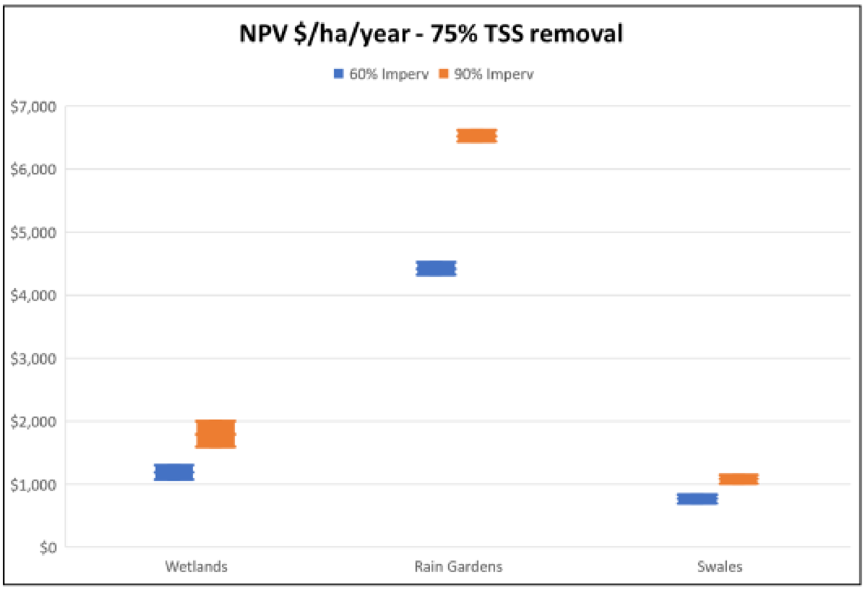


Figure 5-2: Comparison of NPV life cycle costs for differing levels of imperviousness and stormwater management options (Ira et al., 2015)

Moores et al. (2019) describe work undertaken as part of the ‘Activating Water Sensitive Urban Design’ research project, part of the Building Better Homes, Towns and Cities National Science Challenge. Moores et al. (2019) used existing life cycle cost models – COSTnz and the Urban Planning that Sustains Waterbodies (UPSW) decision support tool to model the life cycle costs of a variety of WSD devices to help stormwater professionals understand relative cost differences. Cost data was collected from a total of 16 councils, contractors and consultants from around New Zealand to refine the model assumptions. The results of the life cycle cost modelling are shown in Figure 5-3.



	Low estimate	High estimate
Green roofs	$269	$706
Inert roof	$162	$378
5000 litre rain tank	$358	$804
Permeable driveway	$11	$16
Concrete driveway	$9	$10

Figure 5-3: Indicative life cycle cost estimates for various conventional and WSD devices (Moores et al. (2019))

Moores et al. (2019) augmented the life cycle cost modelling with a literature review which concluded that, in general, WSD is a more cost-effective approach to land development than current conventional forms of development. It found that on average, WSD can result in 14% - 35% savings in site preparation and earthwork costs. Savings from reduced impervious areas and piping associated with a WSD design can vary from 11% - 69%. While some studies found that costs of landscaped areas can increase with WSD, other studies found that landscaping costs were the same or less than conventional development approaches when the landscaping components are integrated with stormwater treatment devices. The review also highlighted that maintenance costs of WSD devices are extremely variable and inextricably linked with device design.

Overall the latest NZ specific research shows that WSD devices used as part of a decentralised management approach (e.g. raingardens, swales) are generally more expensive than equivalent end of pipe solutions typically used in conventional development (e.g. ponds). That said, using WSD as a holistic approach to development including non-structural controls, such as reduced earthworks and less piped infrastructure can be a more cost-effective solution than conventional development in certain contexts when these avoided costs are considered. However, it is difficult to infer potential cost savings in implementing WSD for a given site based on the literature given the high number of variables that have an effect on the costs of WSD (e.g. catchment size, proportion of impervious area, device types etc.). The research also highlights that some WSD devices have lower life cycle costs than others. Specifically, swales and wetlands have much lower costs than raingardens. Given the difficulties in inferring potential cost savings from case studies, a detailed costing study could be undertaken to give WBOPDC a better understanding of the comparative costs of WSD compared to conventional stormwater management for Stage 3.

6 Suitable stormwater management devices

6.1.1 Stormwater management functions

Suitably selected at-source and downstream devices can provide a number of different stormwater management functions to meet the required outcomes for a site. These functions include:

- Detention/attenuation – temporary storage and release to reduce peak flowrates. For the purposes of this report 'detention' will refer to storage of smaller, more frequent events (such as the 90th percentile event) to reduce stream erosion risk and 'attenuation' will refer to storage of larger events (such as a 10 year or 100 year event) for the purpose of preventing flooding.
- Retention – permanent storage of runoff onsite to reduce runoff volumes. This can either be achieved through infiltration to ground or water reuse.
- Water quality treatment – removal of contaminants contained within stormwater runoff. This can be achieved by several treatment processes such as settlement of suspended sediments, filtration, plant uptake etc.

Figure 6-1 shows which stormwater management functions are achieved by certain devices. It is important to note that different devices have varying levels of effectiveness in the treatment of different kinds of pollutants. Stormwater ponds, for example, predominantly rely on settlement of suspended sediments for contaminant removal so have limited effectiveness in removing dissolved contaminants such as heavy metals and nutrients. WSD puts emphasis on the use of "green" devices that can be used to meet multiple ancillary objectives beyond just stormwater management (e.g. public amenity, ecological habitat etc.). Figure 6-2 shows the ancillary benefits provided by each device.

Key ● Effective ○ Partially effective - Not effective	Quantity control					Quality control								
	1% AEP	Detention of 50% and 10% AEP	90^{th} & 95^{th} percentile detention	Groundwater recharge	Retention	Sediment	Gross pollutants	Heavy metals	Oils and grease	Nutrients	Organics	Hydrocarbons	Indicator bacteria	Temperature
Pervious pavement - unlined	-	-	●	○	●	●	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]
Pervious pavement - lined	-	-	●	-	-	●	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]	-[b]
Living roof	-	-	●[a]	-	●	○	NA	○	NA	○	○	NA	○	●
Rainwater tank (no reuse)	-	○	●	-	-	●	NA	○	NA	○	○	NA	○	○
Rainwater tank (with reuse)	-	○	●	-	●	●	NA	○	NA	○	○	NA	○	○
Infiltration device	-	○	●[a]	●	●	-	-	-	-	-	-	-	-	●
Swale (lined)	-	-	-	-	-	●	○	○	○	○	○	○	○	●
Bioretention swale (unlined)	-	-	●	●	●	●	●	●	●	●	●	●	●	●
Rain garden	-	-	●	●	●	●	●	●	●	●	●	●	●	●
Stormwater tree pit[c]	-	-	○	○	●	●	●	●	●	●	●	●	●	●
Planter box	-	-	○	○	●	●	●	●	●	●	●	●	●	●
Constructed wetland	-[d]	●	●	-	○	●	●	●	●	●	●	●	○	○
Wet pond	●	●	●	-	-	●	●	○	○	○	○	○	○	-
Dry pond (detention basin)	●	●	●	-	-	-	-	-	-	-	-	-	-	●

Notes:

NB: Assumes sizing, construction and maintenance are compliant with this guideline's requirements

NA: Not applicable, does not treat this pollutant because it is generally not present in the drainage area

●[a]: Assumes retention of up to the 90^{th} and 95^{th} percentile events

-[b]: Assumes limited water quality treatment for active pervious paving systems. Passive pervious paving is assumed to have some treatment effectiveness if maintained correctly

[c]: Stormwater tree pits are different to street tree pits in that they are specifically designed for stormwater management and must be sized accordingly.

-[d] Wetlands designs should bypass large storm events to protect vegetation and ensure sediments are not resuspended

Figure 6-1: Stormwater management functions achieved by different devices (source: Auckland Council GD01)

Opportunities to improve	Social & cultural values						Environmental values (in addition to water quality)				
• High potential ○ Some potential - Little/no potential	Potential alignment with mana whenua values	Incorporating Te Aranga design principles	Improved amenity	Improved community connectedness	Improved public safety	Education	Habitat improvement	Connecting green corridors	Plant diversity	Bird, insect and reptile diversity	Plant ecosourcing
Pervious pavement	•	○	○	•	•	•	-	-	-	-	-
Living roof	•	•	•	•	○	•	○	○	•	•	•
Rainwater tank	•	○	•	○	○	•	-	-	-	-	-
Infiltration device	○	○	-	○	○	•	-	-	-	-	-
Vegetated swale	•	•	○	○	○	•	○	○	○	○	•
Bioretention swale	•	•	○	○	○	•	○	○	○	○	○
Raingardens	•	•	○	•	•	•	○	○	•	•	•
Stormwater tree pits	○	•	○	•	•	•	○	-	○	○	•
Planter boxes	○	•	○	•	•	•	○	-	○	○	○
Constructed wetland	•	•	•	•	○	•	•	•	•	•	•
Wet pond	-	-	•	•	○	•	•	•	•	•	•
Dry pond (detention basin)	○	○	•	•	•	•	○	○	○	○	○

Figure 6-2: Ancillary benefits of stormwater devices (source: Auckland Council GD01)

6.1.2 Geotechnical considerations for stormwater devices

Infiltration of stormwater into soils can either be "passive" or "active". Passive infiltration generally mimics the natural infiltration of rainwater into the soil by maximising the use of pervious surfaces and paving rather than impervious surfaces. Pervious surfaces allow water to soak into the ground as it would under pre-developed conditions rather than contributing to run-off and overland flow. Active infiltration involves the use of devices such as bioretention devices, infiltration trenches and soak-holes etc. where stormwater runoff from other impervious surfaces is concentrated and fed directly into subsoils. Such devices allow stormwater to infiltrate to deeper levels at faster rates than would usually occur naturally. When active stormwater disposal occurs close to steep slopes it can lead to increased groundwater pressures (and contribute to perched groundwater systems) that may be detrimental to slope stability.

In general, in the greater Tauranga Area, slopes that are greater than 5 m in height and steeper than 1V:2H (approximately 25˚) are vulnerable to landsliding. During the May 2005 storms that affected Otumoetai in Tauranga, it was determined that landsliding was triggered by concentration of overland flow and build-up of groundwater pressure (T+T, 2006).

These are the same factors that have driven the more recent landslides at Omokoroa. In May 2005, the dominant source of water causing the landslides was overland flow.

With regard to active infiltration, guidance previously provided concerning soak-holes for sites of similar geology to the subject site is as follows:

- Such systems should not be installed closer than 15 m to the crest of a slope that is steeper than 1V:2H;
- Where nearby slopes are 1V:2H or steeper, and 5 to 15 m high then soakage systems should be no closer than three times the slope height from the crest; and
- Where there are slopes close by that are 1V:2H or steeper, greater than 15 m high, then the effect of these systems on the stability of the slopes should be specifically assessed.

While the use of soak-holes needs to be minimised as per Condition 6.1 of the Omokoroa CSC, the guidance set out above could also be applied to active infiltration devices such as bioretention devices. Auckland Council's stormwater management device design guidelines (GD01) provide guidance on geotechnical/slope stability considerations for the various devices that can interact with the underlying groundwater (both active and passive infiltration devices). The positioning of water disposal devices relative to slopes is described in the document and is similar to that provided above.

Both sets of guidance discussed above are generally deemed acceptable for use at Omokoroa to indicate where active infiltration devices such as bioretention devices may be viable with regards to slope stability for Stage 3. However, given the variability of the soils in the Omokoroa area it would be prudent to undertake site specific investigations as part of detailed design, where active infiltration systems are proposed to determine local soakage and founding conditions. Alternatively, these devices could be constructed with an impervious liner. This would still allow them to provide other stormwater management functions such as detention and water quality treatment without interacting with the underlying groundwater.

In addition to the above, given its effect on slope stability, overland stormwater flow from development sites needs to be managed in a manner that does not increase the risk of landslides as per Condition 6.1 of the Omokoroa CSC. Some practical methods to mitigate the effect of overland flow on slope stability within Stage 3 may include:

- Creating landforms that do not concentrate overland stormwater flow on susceptible slopes; and
- Where possible, undertaking earthworks such that the finished ground surface falls away from slopes and towards an adjacent road or stormwater management system.

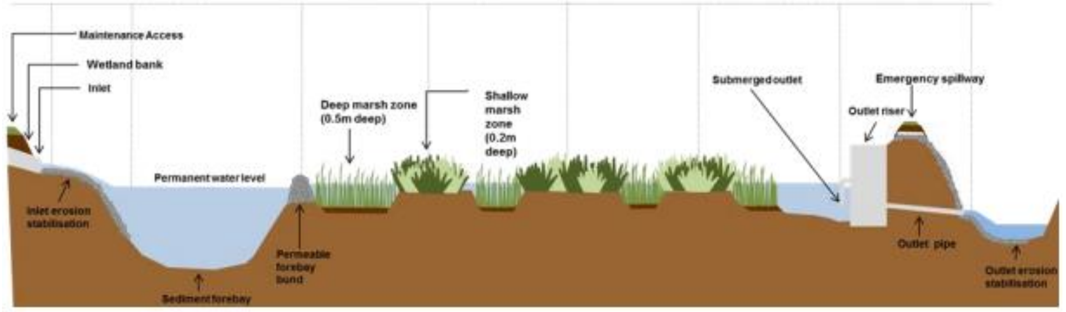
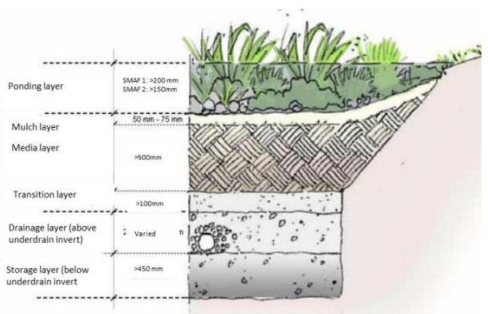
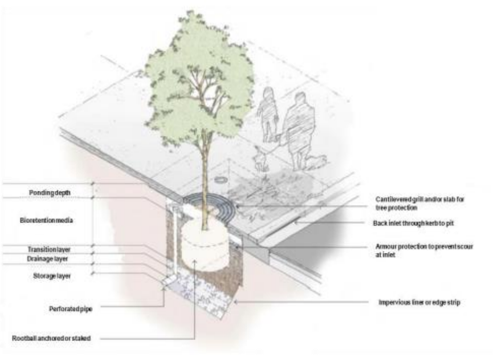
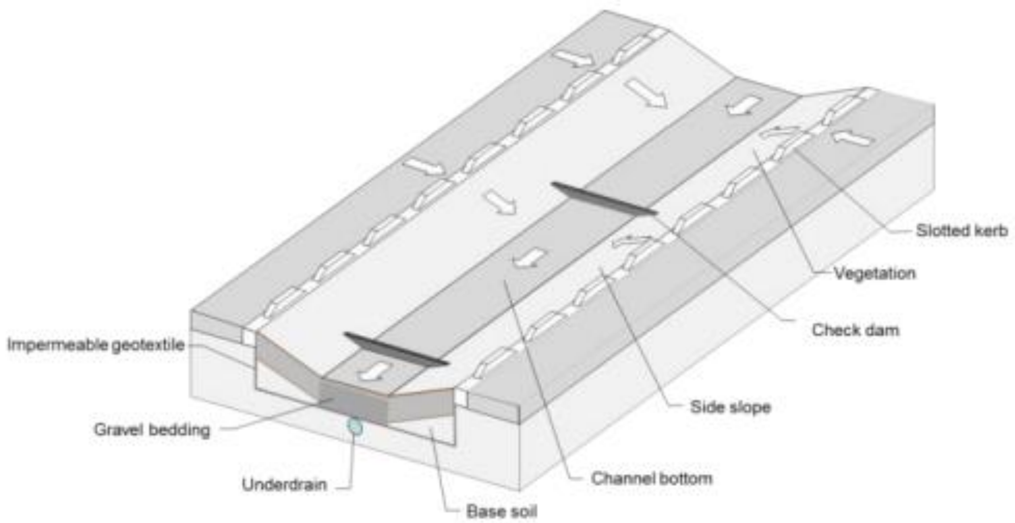
We note that, in some instances, the discharge of overland flow down slopes may be unavoidable. In these cases, we recommend that stormwater is discharged via wetlands at the slope toes. Surface wetting and concentration of overland flow on slopes can cause scour and is a large contributor to slope failure. Where these conditions occur, the slopes will need to be assessed, and on these occasions it may be practical to cover the affected area with a membrane and line it with suitable suitably sized rock to attenuate the water flow and prevent erosion.

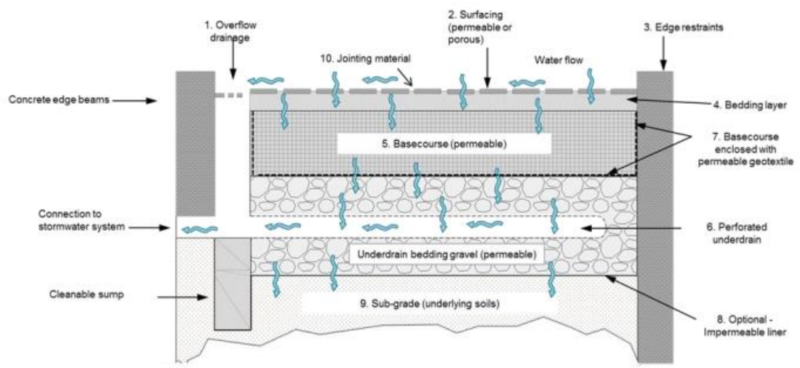
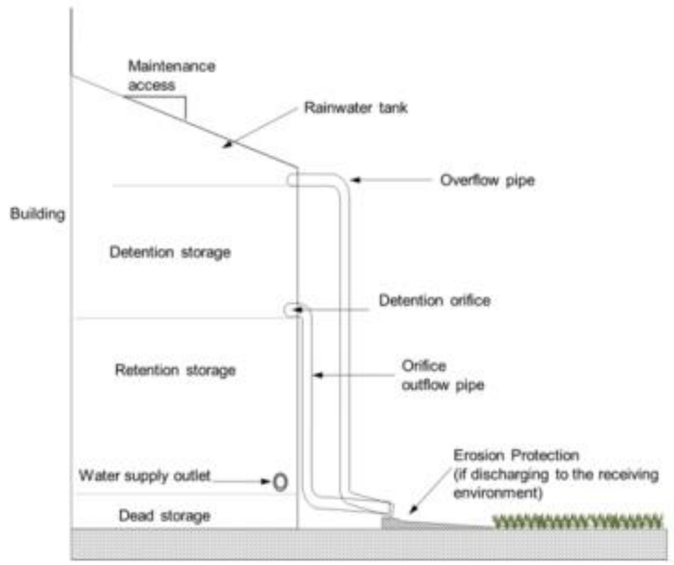
Where water is proposed to be impounded, such as in stormwater treatment wetlands, geotechnical assessments of embankments, adjacent slopes and underlying ground conditions will be required as part of wetland design. In some cases an impermeable liner is required to both maintain permanent water in the base and prevent slope instability.

6.1.3 Summary of suitable stormwater management devices

Table 6-1 below presents a suite of common green stormwater management devices that could be used as part of a WSD approach for Stage 3. This table provides guidance on recommended applications for each device and key considerations for their implementation in Stage 3. However, this table does not replace relevant engineering guidelines and best practice for the design of these devices. Section 7.3 presents a proposed treatment train comprised of these devices that could be adopted to meet the required stormwater management objectives for Stage 3.

Table 6-1: Summary of suitable stormwater management devices

<table>
<tr><th>Device name and schematic</th><th>Description</th><th>Stormwater management function</th><th>Recommended applications in Stage 3</th><th>Key considerations for implementation in Stage 3</th></tr>
<tr><td>Engineered wetlands

</td><td>Constructed stormwater wetlands are ponded areas, densely vegetated with water-loving plants.</td><td>• Detention of small rainfall events.
• Water quality treatment.
• Flood attenuation.</td><td>End of catchment solution for treating stormwater runoff from impervious surfaces.
Recommended for:
• Industrial areas.
• Residential areas (where natural storage areas exist that can be retrofitted).</td><td>• Attenuation only needed where increases in peak flowrates has an effect on privately owned land downstream.
• Wetlands recommended over ponds due to superior water quality treatment and provision of public amenity.
• Should only be used as "offline" devices.
• Geotechnical investigations required as part of wetland design (refer Section 6.1.2). Impervious liners might be required.
• Use of wetlands should be minimised, especially where they would replace areas of existing ecological value in the stream corridors</td></tr>
<tr><td>Bioretention devices (e.g. raingardens/treepits)


</td><td>A bioretention device is a sunken garden with an engineered soil media and an underdrain. These devices pass stormwater through both soil and plants which absorb and filter contaminants before stormwater flows through the underdrain to the surrounding ground or the conveyance system.</td><td>• Detention of small rainfall events.
• Retention (when unlined).
• Water quality treatment.</td><td>• Pedestrian areas.
• Carparks.
• Roads.</td><td>• Very specific maintenance and operation.
• Geotechnical investigations required as part of bioretention device design if unlined (refer Section 6.1.2).
• Must be suitably offset from slopes, structures (such as retaining walls) and road/building foundations.
• If used adjacent to a road, a concrete edge beam or wall may be required for support.</td></tr>
<tr><td>Swales

</td><td>Swales are broad, planted channels used to treat stormwater runoff. They direct and slow stormwater across vegetation, grass or similar ground cover and through the soil</td><td>• Water quality treatment.
• Conveyance of runoff.</td><td>• Roads.
• Carparks.
• Alternative to pipes to conveyance of stormwater to the bottom of the catchment.</td><td>• Simple to construct and operation and maintenance well understood.
• Not suitable where slope is greater than 8% when providing a treatment function. Check dams needed for slopes greater than 5%. Need to be rock lined for slopes greater than 8%.
• If used beside roads driveway access needs to be considered.
• Vegetated swales (i.e. planted with native sedges as opposed to grassed) are generally considered best practice due to reduced maintenance and increased amenity value.</td></tr>
</table>

Device name and schematic	Description	Stormwater management function	Recommended applications in Stage 3	Key considerations for implementation in Stage 3
Pervious pavement 	Any system providing hard or trafficable areas which also provides for downward percolation of stormwater runoff. This includes no-fines concrete or porous asphalt, permeable pavers (water percolates through gaps between pavers), porous pavers (water percolates through the paver) and stabilised loose material (e.g. pebble or shell held in reinforced units or bound by resin).	• Detention of small rainfall events. • Retention (when unlined).	Any flatter areas not exposed to vehicle loads such as: • Pedestrian areas. • Driveways and other impervious surfaces around dwellings. • Footpaths. • On-street parking bays.	• Not suitable for traffic areas of high acceleration, deceleration or turning. • Can only be used on slopes up to 12%. Slopes greater than 5% require paving to have cutoff barriers at intervals to prevent upwelling downslope (i.e. infiltrated runoff being ejected from the pavement). • May be a privately owned device. Some maintenance is required by device owner. • May need impervious liner when used adjacent to roads.
Rain tanks/underground detention tanks 	Rainwater tanks are used to collect water from the roof of a building and detain it prior to release. Water can also be retained for use on site as supplemental water. The water from these tanks can be for household use (flushing the toilet and laundry supply) or outside purposes (such as garden watering and washing cars).	• Detention of small rainfall events. • Retention (when stored runoff is reused on site for other purposes e.g. flushing toilets, irrigation etc.).	• Roofs where there is a water reuse demand. • Providing detention where wetlands aren't suitable and water quality treatment is provided by other devices.	• May increase construction costs if used for private dwellings. • Tanks can occupy a large footprint on residential properties. • Can reduce the use of potable water from public supply for non-potable uses. • Require maintenance and inspection by owner (may require notice on title if a part of the stormwater management system for the catchment). • Engineering design for raintank foundation will be required when located close to slopes.
Living roofs 	A living roof is a roof largely covered by vegetation, growing in a substrate on top of waterproof and root-resistant layers.	• No stormwater effects created that need to be managed.	• Any roofs with a pitch less than 26%.	• Is regarded as pervious surface therefore does not require any further stormwater management. • Higher construction and maintenance costs than equivalent roof types so may only be practicable in certain situations (e.g. where amenity benefit of the living roof is recognised).

7 Proposed water sensitive design approach

7.1 Water sensitive design philosophy

WSD is defined in Auckland Council's WSD guidance document (GD04) as:

"An approach to freshwater management, it is applied to land use planning and development at complementary scales including region, catchment, development and site. Water sensitive design seeks to protect and enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities."

This approach to urban water management is sometimes also referred to as low impact design (LID), integrated water management or sustainable urban drainage (SUDs). WSD is now considered best practice for urban water management in New Zealand by the water engineering practitioners. The principles of WSD are as follows:

- Promote inter-disciplinary planning and design of stormwater systems.
- Protect and enhance the values and functions of natural ecosystems.
- Address stormwater effects as close to source as possible.
- Mimic natural systems and processes for stormwater management.

Historically holistic stormwater management has not been a large part of the urban planning process. "Conventional" stormwater management has sought to convey water away as quickly as possible to prevent flooding. Where treatment of stormwater was provided, the conventional approach was centralised "end of pipe" methods that focused on TSS removal. WSD, on the other hand, aims to minimise hydrological and ecological impacts as a result of urbanisation. Therefore, a WSD approach to stormwater quantity management seeks to match pre-development hydrology by minimising the amount of runoff generated and providing multiple opportunities for infiltration, evapotranspiration and slowing down flow to prevent rapid accumulation of runoff at the bottom of the catchment. Conventional development often utilises kerb, gutter and reticulated systems, which rapidly concentrate flows to the point of discharge. WSD approaches promote dispersed flows across landscape areas or vegetated swales that are rough rather than smooth. In terms of stormwater quality management WSD seeks to minimise the generation of pollutants and capture of a range of predicted contaminants as close to the source as possible, through a complementary sequence of stormwater management responses that utilise natural treatment processes.

Figure 7-1: Example of suburban development that incorporates a water sensitive design approach (Lewis et al., 2013)

The subsections below set out a high-level framework for stormwater management in Stage 3 that aligns with a WSD approach. It is presented as a hierarchy of approaches and considerations for development, starting with the most effective top of catchment interventions (source control and at-source management) and finishing with end of catchment interventions such as downstream devices and enhancing the receiving environment. This framework can be used as a starting point to form the general elements of the stormwater treatment train[2] that will deliver the stormwater management outcomes for Stage 3.

[2] A treatment train is the combination of sequential stormwater management responses that collectively deliver stormwater quality and quantity objectives for a site.

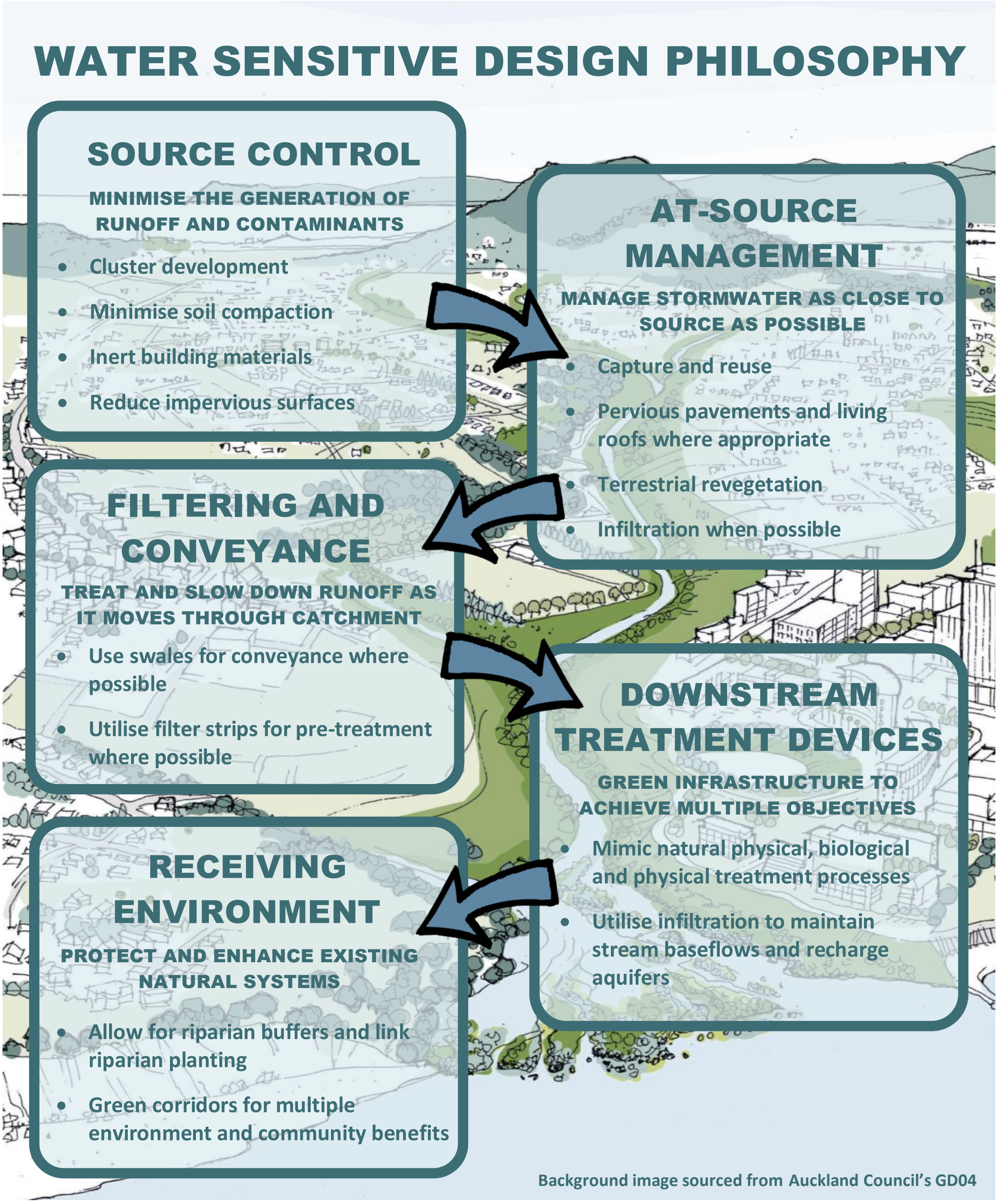


Figure 7-2: Water sensitive design philosophy (background image sourced from Auckland Council's GD04)

7.1.1 Source control

Source controls seek to minimise the generation of stormwater and its associated contaminants. The following source control measures should be considered for the site:

- Minimise land disturbance and cluster development. 'Clustered development' involves increased density of built form in appropriate areas of a site or a catchment in order to preserve the balance of an area for ecosystem services.

- Minimise the degradation and compaction of site soils. This may also involve consideration of alternative land development approaches other than the traditional 'cut-to-fill' operations for site levelling.
- Apply best practice or enhanced sediment and erosion controls during construction to reduce sediment discharge.
- Design buildings using "inert" materials for cladding and roofing to minimise contaminant generation.
- Minimise impervious surfaces in the development. Reduced imperviousness increases opportunities for rainfall to be attenuated within vegetation and soils and is also likely to reduce the contaminant load. Minimising impervious surfaces may include the following kinds of approaches:
  - Shared driveways.
  - Shared road surfaces for low traffic environments.
  - Single footpaths in road corridors
  - Replacing impervious surfaces with pervious paving, living roofs, etc.
  - Aggregating buildings and ancillary structures such as garages to reduce total footprint and access requirements.

7.1.2 At-source stormwater management

WSD promotes the management of stormwater as close to source as possible to reduce the potential for lower catchment stormwater effects. The following measures should be considered for the site:

- Capture and reuse of rainwater for buildings and landscape areas where appropriate.
- Use at-source stormwater management devices such as pervious pavements and green roofs where appropriate.
- Include terrestrial re-vegetation in public road corridors, public reserves etc. throughout the catchment to reduce runoff volumes, decrease runoff temperature and provide some water quality treatment.

7.1.3 Filtering and conveyance

Both filter strips and swales achieve some degree of stormwater treatment while conveying it through the catchment. Specific mechanisms include contact with soil to detain runoff, increased roughness to slow flow velocities and increase time of concentration and filtering sediment through plant and soil materials. The following measures should be considered for the site:

- Use swales for stormwater conveyance where possible as an alternative to pipes.
- Consider filter strips as a pre-treatment before other stormwater devices such as swales, raingardens and tree pits.

7.1.4 Downstream treatment devices

The following measures should be considered when considering downstream treatment devices for the site:

- Treat stormwater as close to the source as possible.
- Utilise stormwater treatment devices that mimic natural physical, biological and physical treatment processes (e.g. bioretention).

- Integrate the use of stormwater treatment devices into urban design and the landscaping requirements for the site.

Further guidance on the selection of downstream treatment devices is given in Section 6.

7.1.5 Receiving environment

Protecting and enhancing existing natural systems such as mature vegetation, watercourses and wetlands can allow them to be used as part of the stormwater management system. The following measures should be considered for the site:

- Identify ephemeral and permanent streams and preserve a riparian buffer around them in the development layout.
- Preserve and restore riparian vegetation along banks, natural floodplains and wetland margins, including linking areas of riparian vegetation, to create continuous green corridors.
- Maintain springs and stream baseflows from groundwater by minimising reductions in infiltration from pre-developed levels.

7.2 General WSD management approach

To comply with the CSC, we propose the following stormwater management objectives for the site:

- Water quality treatment of all impervious surfaces, with a focus on providing a higher level of treatment for the land uses which will generate most contaminants (e.g. industrial areas and arterial/high use roads). The exception to this is the rural-residential zone (refer Section 7.3.2 for further discussion).
- Detention of the 90th percentile storm for areas that do not discharge directly to the Tauranga Harbour to mitigate stream erosion risk (subcatchments W2, N2 and E1).
- Attenuation of large rainfall events (i.e. greater than a 90th percentile event) will only be provided where there is private property or infrastructure downstream that would be adversely affected by an increase in flood levels.

Wetlands will be used to provide water quality treatment and detention (where necessary) for industrial areas. Decentralised approaches are generally more difficult to implement for industrial areas given the large lot sizes and high levels of imperviousness. For residential areas the preference is for a decentralised approach. However, given there are some existing informal storage areas and artificial ponds that could be retrofitted into engineered treatment wetlands to service the residential areas, it is proposed that these be utilised instead of decentralised devices. The number of new wetlands should be minimised as far as practicable, especially where they would replace areas of existing ecological value in the stream corridors. This is because wetlands only treat stormwater at the bottom of the catchment, can result in elevated effluent temperatures and their construction can have adverse effects on existing stream habitat.

Based on these principles, it is proposed that three new wetlands are established for managing stormwater for the industrial areas and the two existing storage areas are retrofitted into treatment wetlands to manage stormwater from the residential areas (refer Figure 7-3 for proposed locations). This is a significant reduction in the number of wetlands from the Omokoroa SMP. The existing wetland in subcatchment N2 will also be retained. This wetland was designed by Lysaght as part of the Kaimai Views subdivision.

We understand that it is WBOPDC's intention to own and manage stormwater reserves within the stream corridors. On this basis, attenuation would likely only be required for subcatchment N2 which drains to the golf course north of the railway embankment. From Lysaght's design report (Lysaght, 2018) we understand the existing wetland in this subcatchment has been designed to provide water quality treatment, detention and attenuation assuming full development of the entire subcatchment. Therefore, no further modifications to the wetland would be required to service the additional development shown on the structure plan as part of Stage 3.

Currently the proposed management approach for subcatchment N1 is to not provide any attenuation. However, further investigation should be undertaken to confirm whether the railway culvert at the bottom of subcatchment N1 has sufficient capacity to pass additional flow, or whether any upgrade of this culvert is required. For the remaining wetlands, only water quality treatment will be provided. Detention of small rainfall events will also be provided where the wetland does not discharge directly to tidally influenced areas.

It is recommended that planning rules are added to the Omokoroa structure plan to minimise the generation of stormwater from impervious areas and entrained contaminants. To minimise stormwater volume it is proposed that maximum impervious limits are set for the low density residential and rural residential zones. If ambitious limits are set on imperviousness (i.e. relatively low levels of imperviousness permitted) this could encourage the adoption of alternative development forms such as multi-storey dwellings or mitigation measures such as pervious pavement/living roofs. Provision could be made for exceedance of the imperviousness limits if onsite mitigation is provided such as detention/retention using a raintank. However further work would be required to determine what a suitable level of onsite mitigation would be for levels of imperviousness beyond the permitted level. Other provisions of the Omokoroa structure plan could also assist in minimising runoff generation, such as reduced front yard requirements to reduce driveway lengths or reduced minimum road widths. Contaminant generation could be minimised through rules requiring “inert” building materials for building exteriors (i.e. no unpainted zinc or copper products unless additional treatment provided onsite).

If devices that promote active infiltration (such as unlined bioretention devices) are used they should be located and designed such that they do not increase slope instability risk (refer guidance in Section 6.1.2).

Figure 7-3 shows the assumed post development subcatchments for the purposes of developing a high-level stormwater approach. These post-developed subcatchments are based on the existing subcatchments with some rationalisation based on the locations of roads and proposed land use zoning. Post-developed topography and drainage for Stage 3 should carefully consider the potential effects on changing the balance of flows between subcatchments, particularly the effect on peak stream flows and erosion risk. For example the stormwater management approach indicated in Figure 7-3 includes maintaining the overland flowpath down Prole Road (subcatchment N1) rather than re-grading the land to drain into the stream corridors on both sides of the Prole Road (subcatchments W2 and N2). The former approach was adopted to prevent increasing the size of subcatchment W2 which would result in peak flow increases within the stream corridor. This kind of effect cannot be mitigated with detention of the 90th percentile storm which only addresses changes in peak flows as the result of land use changes. These issues will need careful consideration as part of detailed design of Stage 3.

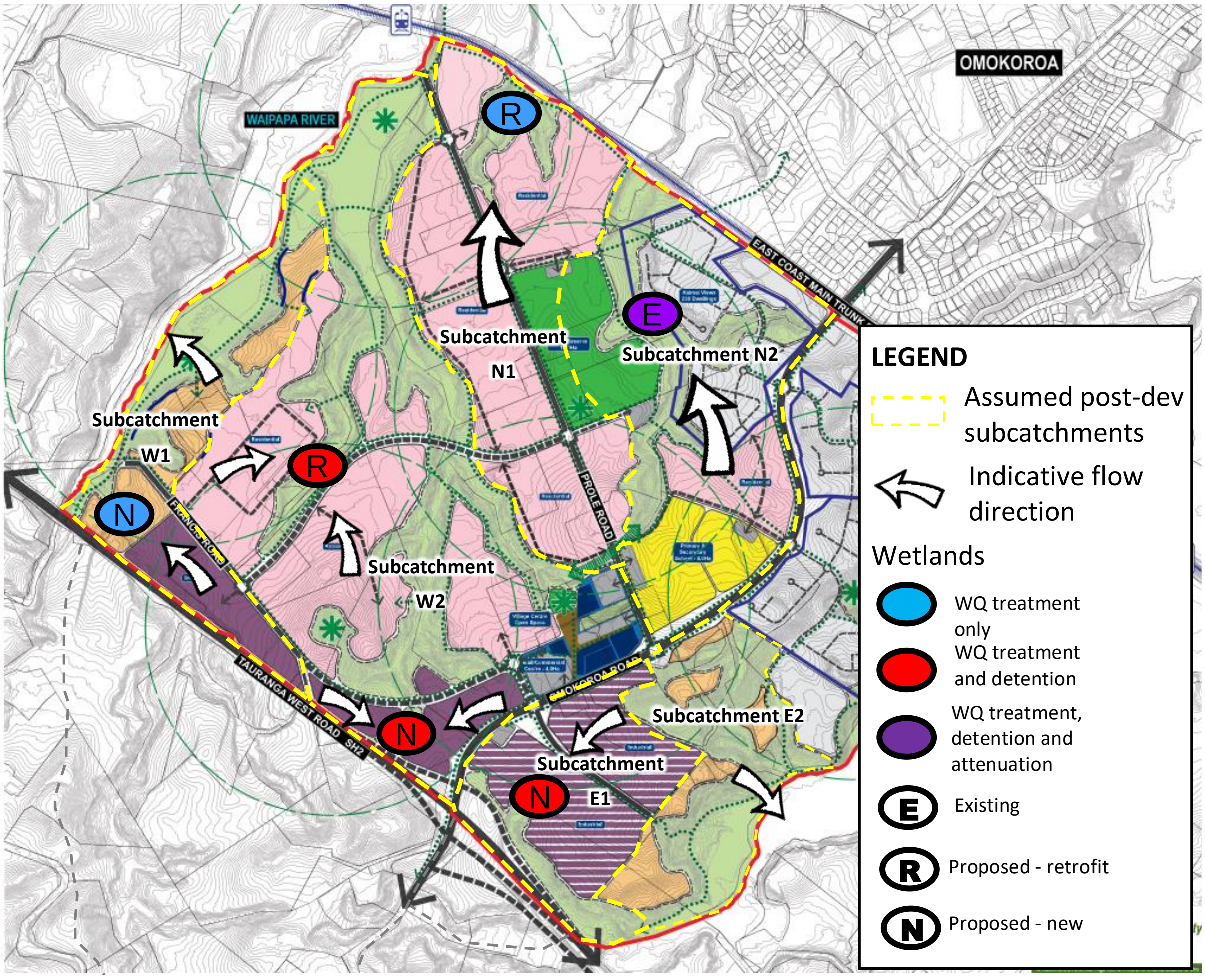


Figure 7-3: Proposed wetland locations

The following approaches are also proposed to be implemented site-wide:

- The use of swales is preferred over raingardens, as swales also provide a conveyance function and are lower cost to construct and maintain.
- Green outfalls should be considered for pipe outlets. A green outfall involves a length of naturalised open channel (i.e. with vegetation and roughness elements) to reduce flow velocities and energy before stormwater reaches the receiving stream. Where pipe outlets are located on steep topography appropriate energy dissipation will need to be incorporated into the outlet to mitigate risk of local scour.
- Overland flow paths for larger storm events need to be identified and protected as part of the subdivision design stage.
- Gross pollutant traps should be incorporated where possible as a form of pre-treatment for downstream devices. This could be in the form of catchpit litter screens or end-of-pipe capture methods.
- Transport links through stream gullies (both vehicular and for pedestrians) should not act as an impediment to the conveyance of flood flows or to fish passage. Stream crossings should be minimised and, where they are required, should be in the form of bridges or fords (for pedestrian crossings). Embankments with culverts are no longer considered best practice where there are viable alternatives.

- The area of impervious surfaces within the road corridor should be minimised. This could be achieved with reduced road widths and/or using pervious pavement or gobi blocks for on street parking.
- Maximise the use of vegetation throughout the development. Trees in particular should be used where possible in road corridors, stream corridors and other public reserve areas to reduce the temperature of runoff entering the receiving environment. All treatment wetlands should have appropriate planting to reduce temperature effects.

7.3 Proposed treatment trains

This section presents the proposed treatment trains for Stage 3 of Omokoroa that have been developed using the framework presented in Section 7.1 to meet the objectives summarised in Section 7.2. Different treatment trains are presented for each proposed landuse zone. It should be noted while the treatment trains presented are considered the best practicable option, other approaches and devices could be used to achieve the same stormwater management objectives.

7.3.1 Low density residential

The proposed low-density residential areas comprise the majority of the site and generally drain to the stream corridors rather than directly to the Tauranga Harbour (refer structure plan map in Appendix A). Two options are presented for the treatment train used in the low-density residential zones – a predominantly piped option and a predominantly non-piped option.

Predominantly piped option

The piped option would involve a conventional kerb, gutter and piped network for the conveyance of primary flows[3]. For the piped option runoff from residential roofs and impervious surfaces would drain to the kerb and gutter system in the road corridor. Runoff would then be captured via inlets such as catchpits and conveyed in the reticulated network to the downstream treatment wetland. In the piped option secondary flows[4] would be conveyed overland in the road corridors.

Generally, stormwater from low density residential zones is proposed to be conveyed to downstream treatment wetlands which will provide water quality treatment to stormwater from all impervious surfaces and also detention in some cases (e.g. where not discharging directly to the harbour). The locations of the proposed wetlands are shown in Figure 7-3. For some areas it may not be practicable to drain to a downstream wetland, due to site topography. In these cases, decentralised methods should be considered. Water quality treatment could be achieved using treatment swales in the road (see non-piped option below) and if detention is also required, this could be achieved with onsite raintanks or communal detention basins.

It is proposed that additional treatment is provided for arterial roads, as they will have higher daily traffic volumes and therefore generally higher contaminant loads. It is proposed that near-source devices such as swales or bioretention devices are used to treat stormwater from arterial roads. Further work should be undertaken to identify evidence-based criteria to determine which roads may require additional treatment. As an example, the Auckland Unitary Plan has additional treatment requirements for 'High Use Roads', which are defined as having daily traffic volumes greater than 5000 vehicles per day.

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[3] Primary flows are those generated from a frequent rainfall event (generally the 10 year average recurrence interval (ARI) design storm) and are captured and conveyed to achieve serviceability design criteria such as maintaining road safety.
[4] Secondary flows are those generated from a high intensity rainfall event (generally the 100 year ARI) and are designed to maintain public safety and prevent damage to infrastructure and buildings.

Non-piped option

The non-piped option would involve incorporating conveyance swales into the road corridor. The purpose of these swales would be two-fold; an additional level of water quality treatment and conveyance of flows to the downstream treatment wetlands. In the non-piped option the wetlands would still be the primary means of achieving water quality treatment and in some cases provide detention (as this cannot be provided by the conveyance swales).

Some areas of land zoned low density residential may be difficult to drain to the wetlands due to site topography. Where no detention is required (e.g. areas discharging directly to the harbour) the conveyance swales would provide water quality treatment so treatment in a downstream treatment wetland is not necessary. If detention is required, this could be achieved using on-site raintanks or communal detention basins.

This non-piped solution provides a more resilient conveyance network (e.g. no risk of inlet/pipe blockage, less risk of rupture/disruption from seismic events etc.) and would also act to slow down flow to prevent rapid accumulation of runoff at the bottom of the catchment. These swales could be located either in the road median or the shoulders of the road. Some minor pipework may be required to connect swales across intersections. Where roads are steeper (longitudinal grade > 8%) swales are not a suitable solution. For these steeper roads a conventional kerb, channel, pipe system would be required.

7.3.2 Industrial

Industrial zones are proposed in the structure plan on both sides of Omokoroa Road, just to the north of SH2 (refer Appendix A). It is proposed that these areas are serviced using conventional kerb, gutter and pipe systems. Non-piped approaches are difficult for industrial areas due to large lot sizes, high site building coverages and high levels of imperviousness leading to large overland flowpaths developing. These characteristics make decentralised approaches difficult to implement in industrial areas. Therefore, centralised wetlands will be used to provide water quality treatment and detention (where necessary) for industrial areas. The locations of the proposed wetlands are shown in Figure 7-3. Given the likely relatively high levels of contaminants in stormwater runoff from industrial areas, it is proposed that enhancements such as ‘floating treatment wetlands’ are considered for these wetlands to increase the level of contaminant removal achieved (dissolved contaminants in particular). It is also proposed that additional treatment is provided for arterial roads with near-source devices such as swales or bioretention devices.

7.3.3 Commercial/village centre/school campus

A village centre, commercial zone and school campus are proposed near the intersection of Omokoroa Road and Prole Road (refer structure plan map in Appendix A). This area will typically be comprised of large roof areas, carparks, pervious open spaces and sealed pedestrian areas. Therefore, it is proposed that these areas are serviced using conventional kerb, gutter and pipe systems as a non-piped approach would not be suitable in this context.

The school campus is within subcatchment N2 and so can be fully managed using the existing downstream wetland. For the carparks, roads and other impervious areas associated with the village centre and commercial areas it is proposed that they are managed using distributed bioretention devices to provide water quality treatment and detention. These could likely be integrated into the landscaping requirements for the site. For roof areas associated with the village centre and commercial areas it is proposed that water quality treatment and detention is provided by a combination of bioretention devices and/or smaller wetlands. If wetlands are used in this area, it is recommended that they are situated within the open spaces of the village centre rather than in the stream gully to the north. This is due to the high ecological values that already exist in the stream gully which could be adversely affected by the construction of new wetlands. Alternatively, if living roofs are used for roofs, then no stormwater management is required for these surfaces, as the runoff behaviour is likely to be similar to the pre-developed state and contaminants will not be generated.

7.3.4 Rural residential

The proposed rural residential areas are located on the periphery of the site, on both sides of the peninsula (refer structure plan map in Appendix A). There are already a number of existing lifestyle properties in these areas so landuse changes, which would have a material effect on stormwater generation, in these areas are expected to be minor. Given the assumed low level of imperviousness in these areas, it is proposed that no formal water quality treatment of residential roofs or driveways is provided. Because these impervious surfaces are generally disconnected (i.e. runoff must travel over pervious surfaces to the receiving environment) some degree of informal treatment will be achieved. It is proposed that the roads that service the rural residential areas have roadside swales for conveyance rather than a reticulated pipe network. These swales will also provide some water quality treatment for the roads. Where road grades are too steep for grassed/vegetated swales (>8% longitudinal grade), pipes or rock-lined channels may need to be used for conveyance.

7.3.5 Summary of proposed treatment trains

Table 7-1 presents a summary of the proposed stormwater management devices for each zone. Figure 7-4 presents a schematic representation of the proposed treatment train for each zone.

Table 7-1: Summary of proposed stormwater management devices

Zone	Conveyance method	Stormwater management devices
Low density residential	Piped option – Primary flow piped, secondary flow overland	• Wetlands where existing storage areas exist • Treatment swales/bioretention devices for arterial roads only • Conveyance swales and raintanks/detention basins where wetlands not practicable
	Non-piped option – Both primary and secondary flow overland	• Wetlands where existing storage areas exist • Conveyance swales on all roads • Raintanks/detention basins may also be required to provide detention (i.e. in addition to conveyance swales) where wetlands aren't practicable
Industrial	Primary flow piped, secondary flow overland	• Wetlands with enhancements such as floating treatment wetlands • Treatment swales/bioretention devices for arterial roads only
Commercial, village centre and school campus	Primary flow piped, secondary flow overland	• School campus managed in existing pond in subcatchment N2 • Bioretention devices for carpark and paved areas • Bioretention devices/wetlands for roof areas • Living roofs can be used in-lieu of stormwater management devices for roof areas
Rural residential	Both primary and secondary flow overland	• Conveyance swales on roads

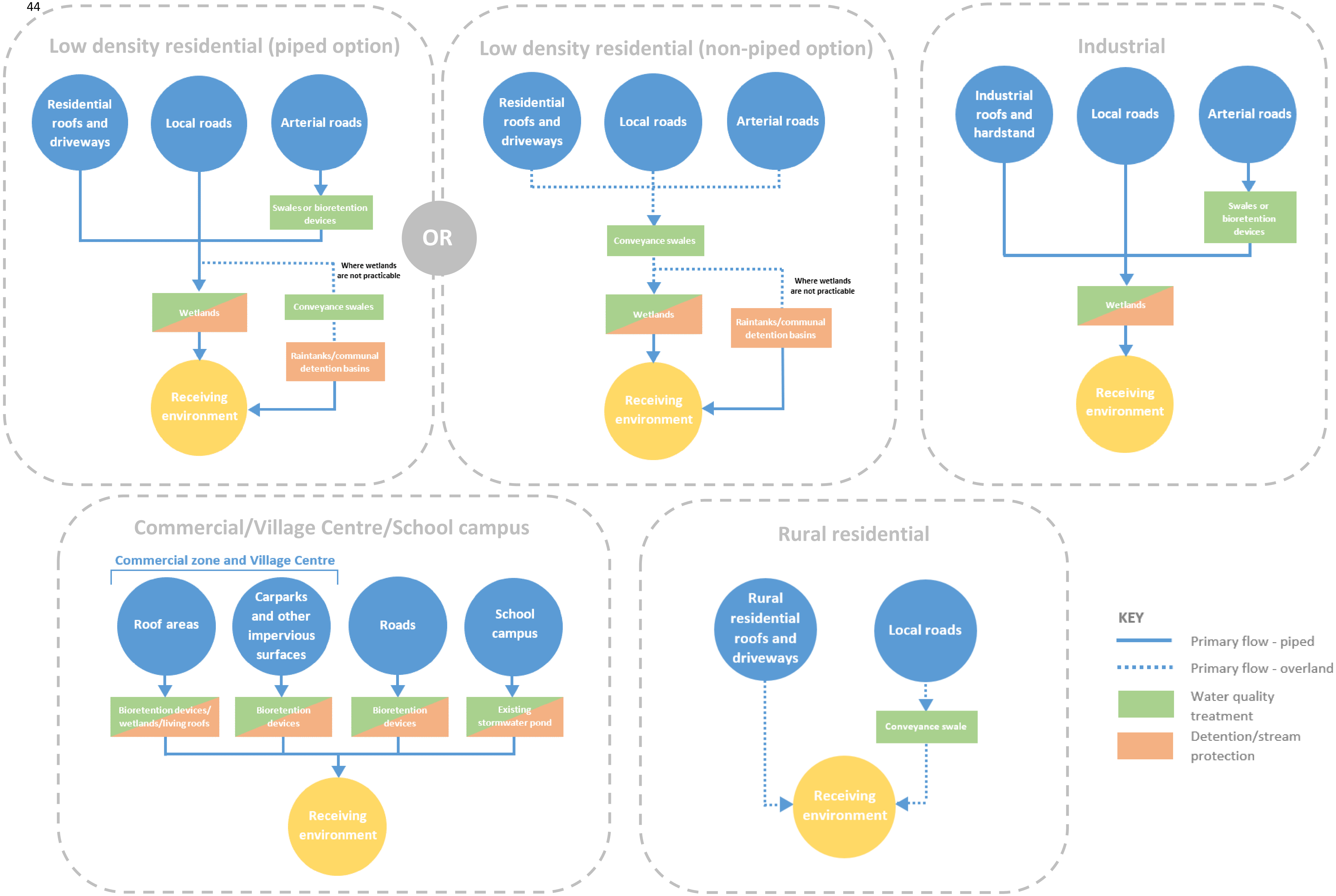

Figure 7-4: Schematic of proposed treatment trains

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9 Applicability

This report has been prepared for the exclusive use of our client Western Bay of Plenty District Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:

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Joshua Hodson

Water Resources Engineer

Authorised for Tonkin & Taylor Ltd by:

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Reuben Hansen

Project Director

JTIH
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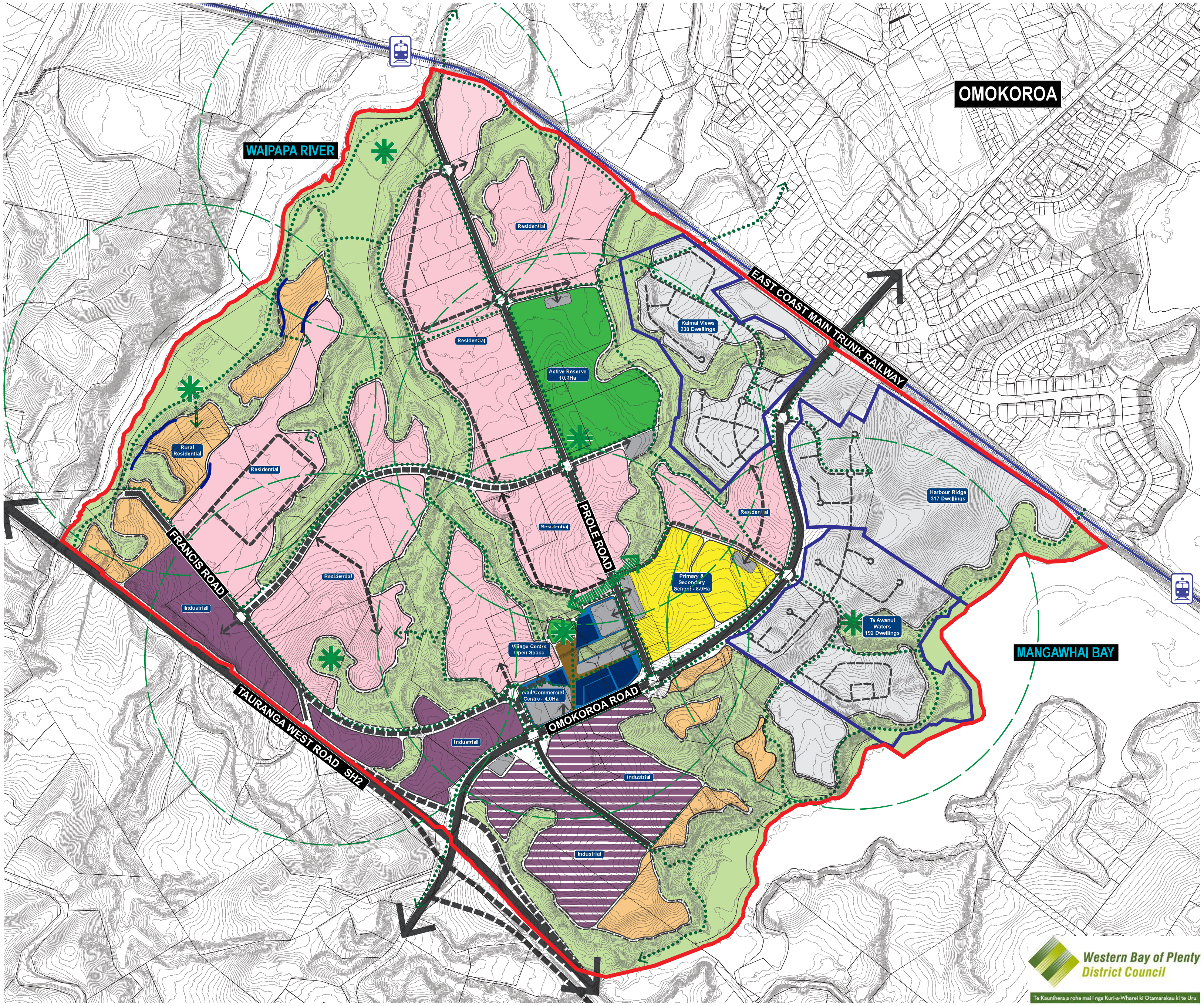
Appendix A: Proposed Omokoroa Stage 3 structure plan

LEGEND

- Study Area
- Existing road network
- Possible future urban road network consideration
- Proposed signalised intersection
- Proposed roundabout
- Proposed major pedestrian/cycle network
- Local Park - 500m Catchment (5min walk)
- Constrained Land. Inclusive of:
  - Slope greater than 1:4 (25%)
  - Stormwater ponds, stormwater management reserves & stormwater reserves
  - Tsunami evacuation zones - red, orange & yellow
  - Partial areas of widespread liquefaction
  - Archaeological sites
  - Significant ecological features/RAP
  - Areas prone to instability
  - Landscape feature S8/S8A - Tauranga Harbour Landscape management area
  - Private conservation reserves
- Active Reserve
- WBOPDC owned land, inclusive of community centre.
- Village Centre
- Low Density Residential
- Rural Residential
- Primary and Secondary School
- Retail and Commercial
- Industrial Land



Omokoroa

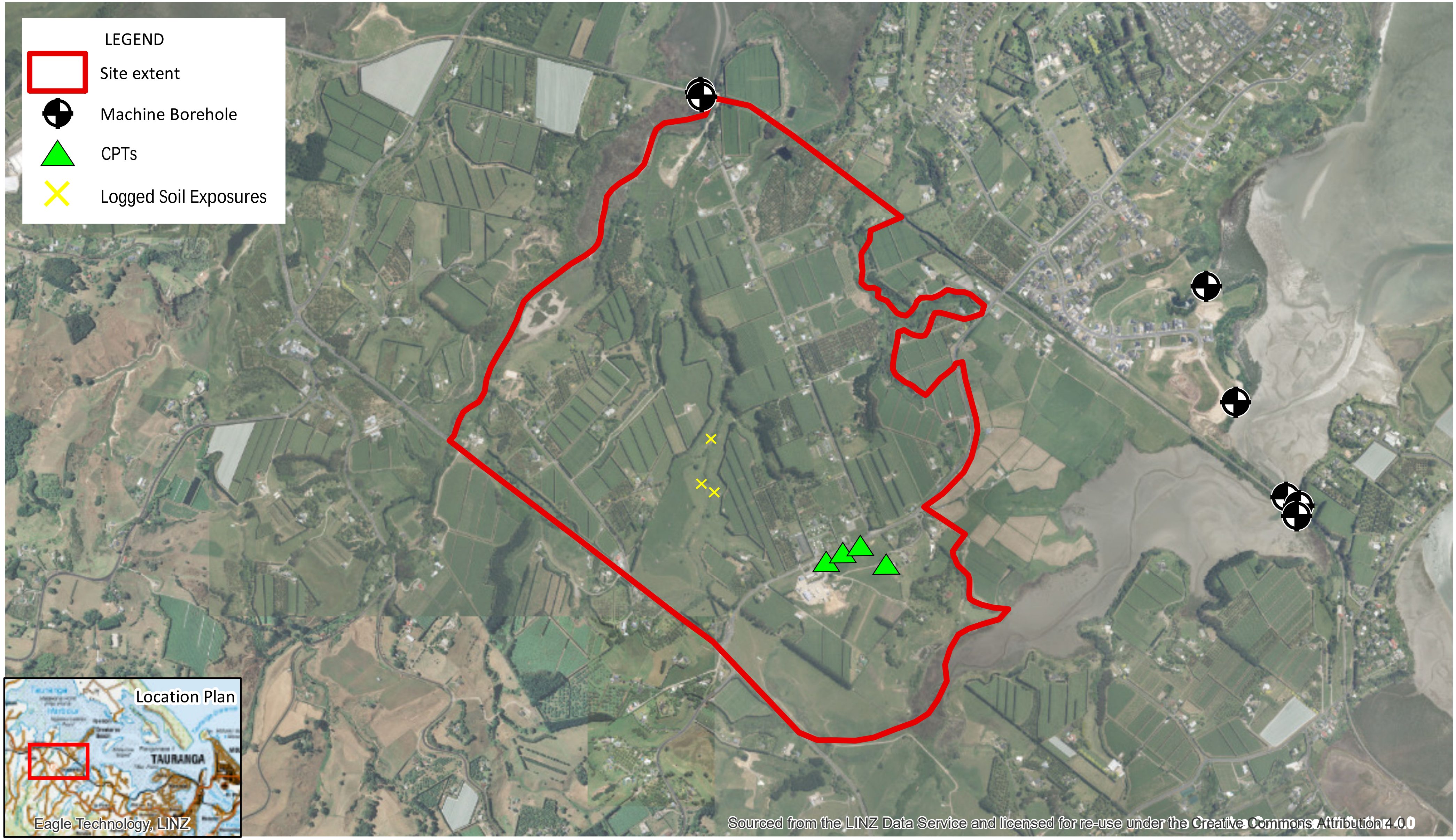
Structure Plan Option 5

PRELIMINARY FOR DISCUSSION PURPOSES ONLY

Scale 1:5000 @ A1 | 28th November 2018 | Project No 138288-17

RPS

Appendix B: Geotechnical data plan



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PROJECT No. 1012404.1000

WESTERN BAY OF PLENTY REGIONAL COUNCIL

OMOKOROA STAGE 3 STRUCTURE PLAN
WESTERN BAY OF PLENTY
Local Ground Investigations and Logged Soil Exposures

FIGURE No. Figure B1

Rev. 0

Appendix C: Ecology and erosion susceptibility assessment results

Memo

To:	**Josh Hodson**	**Job No:**	**1012404.1000**
From:	**Selene Conn**	**Date:**	**17 February 2020**
Subject:	**Streamwalk Assessment Methods for the Omokoroa Stage 3 Water Sensitive Design Plan**		

1 Introduction

This memo summarises the methods used to score erosion susceptibility and ecological value for the stream walkover conducted as part of the Omokoroa Stage 3 Water Sensitive Design (WSD) Plan.

2 Method

2.1 Erosion susceptibility scoring

Tonkin + Taylor's (T+T's) 'erosion susceptibility method' was used to produce a score of erosion susceptibility, and to help identify and describe active erosion processes. This method has been developed by T+T and uses parameters from a range of other international geomorphic methods, including the following:

- AusRIVAS Physical Assessment Protocol (Parsons et al 2001);
- Fluvial Audit Methodology (Sear et al. 1995);
- River Styles Framework (Brierley and Fryirs, 2005);
- Index of Stream Condition (White and Hardy, 1997);
- Pennsylvania Aquatic Community Classification Method (Walsh et al, 2007);
- Function-Based Rapid Stream Assessment Methodology (Starr et al, 2015); and
- Restoration Indicator Toolkit (Parkyn et al. 2010).

The parameters assessed for the T+T erosion susceptibility method include:

- Valley confinement;
- Sinuosity;
- Bed and bank material;
- Hydrology;
- Dominant geomorphic processes;
- Reach slope;
- Channel shape;
- Bank shape;
- Bank slope;
- Percentage of active bed and/or bank erosion;
- Channel modifications;
- Width to Depth ratio;

- Riparian vegetation type;
- Riparian vegetation continuity;
- Bar type; and
- Several other factors affecting bank stability.

Each of the parameters are assigned a weighting based on that parameter's perceived contribution to erosion processes, with higher scores being assigned to those values considered to contribute the most to erosion.

Weightings are applied separately for bed erosion processes and bank erosion processes, to differentiate between those reaches likely to experience on-going incision, or those reaches that are more likely to experience bank erosion independent of bed erosion.

The intention of differentiating between bed and bank erosion is to help guide management actions, as those reaches displaying a high bed erosion potential may require different interventions than those reaches that are displaying bank erosion independent of bed processes. This should help to get the best outcomes for stream restoration projects from the outset of the project.

Erosion susceptibility values have been grouped into ranges and then characterised as "Low" erosion susceptibility, "Moderate" erosion susceptibility, "High" erosion susceptibility or extreme erosion susceptibility (Table 2-1). As the erosion susceptibility assessment method does not solely rely on active erosion, this rating helps managers to identify those reaches that may experience severe and ongoing erosion in the future if catchment conditions change, rather than waiting for that erosion to occur before management actions are initiated.

Table 2-1: Erosion susceptibility ratings for the erosion susceptibility assessment

Erosion susceptibility ranking	Erosion susceptibility score ranges
Low	0-5
Moderate	6-10
High	11-19
Extreme	20-25

2.2 Ecological values assessment

Aquatic ecological values were assessed on site using the National Rapid Habitat Assessment (RHA) developed by the Cawthron Institute to provide a quick and easy to use method to indicate ecological habitat value and allow quantitative comparison of values between sites (Clapcott et al., 2015). This method has been used by Northland Regional Council and the Department of Conservation between 2013 and 2014 and was trialled on over 500 sites nationally before the method was provided for wider use (Clapcott et al., 2015). This method includes scoring a site from 1-10 for the following values:

- Deposited sediment;
- Invertebrate habitat diversity;
- Invertebrate habitat abundance;
- Fish cover diversity;
- Fish cover abundance;
- Hydraulic heterogeneity;
- Bank erosion;

- Bank vegetation;
- Riparian width; and,
- Riparian shade.

The overall score is out of 100. For the Omokoroa Stage 3 WSD plan, the scores across all reaches assessed were grouped into rankings, based on the ecological value of the reaches assessed (refer Table 2-2).

Table 2-2: Ecological habitat value rakings for the Omokoroa Stage 3 WSUD plan

Ecological habitat value rankings	Ecological habitat value score ranges
Low	14-30
Moderate	31-39
High	40-67

Additional key ecological attributes that were assessed during the site visit included:

- Stream bed type (silt dominated: 'soft bedded', gravel-boulder dominated: 'hard bedded');
- Potential spawning habitat;
- Spot water quality measurements (handheld YSI Professional Plus multimeter: temperature, dissolved oxygen, pH, and specific conductivity);
- Any fish species observed (guided by New Zealand Freshwater Fish Database records);
- Any fish passage barriers;
- Artificial modifications (dams, stream straightening, bank modifications, development/disturbance); and
- Fencing and riparian margin integrity.

3 Results

3.1 Erosion susceptibility results

Table 3-1: Breakdown of erosion susceptibility scores

Reach	Omo_W2_1	Omo_W2_2	Omo_W2_3	Omo_W2_5	Omo_W2_6	Omo_W2_7	Omo_W2_8	Omo_W2_9	Omo_W2_10	Omo_W2_11	Omo_W2_12	Omo_N2_1	Omo_N2_2	Omo_N2_3	Omo_N2_4	Omo_N2_5	Omo_E2_1	Omo_E2_2	Omo_E1_1	Omo_E2_3
Date	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	14/11/2019	15/11/2019	15/11/2019	15/11/2019	15/11/2019	15/11/2019	15/11/2019	15/11/2019	15/11/2019	15/11/2019
Collector	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR	JAGR
Photo	180-190	191-228	229-238	247-254	239-2460	260-262	265-277	292-295	295-299	278-292, 300-305, 309-314	315-324	371-388	389-399	423-431+466+467+468	400-421	432-440	506-514	491-505	523-543 and others from phone	515-516
Valley confinement	Confined	Confined	Confined	Unconfined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined	Confined
Bank score	0.1	0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bed score	1	1	1	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Low sinuosity	Straight
Bank score	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bed score	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Stream type	Low sinuosity degraded valley fill (spring fed)	Constructed ponds	Cut and Fill (valley fill)	Incised, straightened, low velocity tidal stream	Intact valley fill	Intact valley fill	Degraded valley fill	Degraded valley fill	Degraded valley fill	Intact valley fill	Degraded valley fill	Intact valley fill	Degraded valley fill	Degraded valley fill	Valley fill	Degraded valley fill	Partially degraded valley fill	Partially degraded valley fill	Degraded valley fill	Modified degraded valley fill
Bank material	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt
Bank score	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bed material	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt	Sand/Silt
Bed score	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dominant B-axis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lag B-axis	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Flow	Intermittent	N/A	Permanent	Tidal	Permanent	Permanent	Permanent	Permanent	Intermittent	Intermittent	Permanent	Intermittent	Intermittent - Permanent	Permanent	Permanent	Permanent	Intermittent	Intermittent	Intermittent	Intermittent
Bank score	0.5		1	0.2	1	1	1	1	0.5	0.5	1	0.5	0.5	1	1	1	0.5	0.5	0.5	0.5
Bed score	0.5		1	0.2	1	1	1	1	0.5	0.5	1	0.5	0.5	1	1	1	0.5	0.5	0.5	0.5
Dominant geomorphic process	Moderate degradation	N/A	Moderate aggradation	Neutral	Extreme bed aggradation	Moderate aggradation	Moderate aggradation	Moderate aggradation	Moderate aggradation	Moderate aggradation	Moderate aggradation	Neutral	Moderate aggradation	Moderate aggradation	Moderate aggradation	Moderate aggradation	Neutral	Neutral	Moderate aggradation	Neutral
Bank score	0.5		0.3	0.3	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Bed score	0.2		0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.2
Reach slope	Gentle	N/A	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Gentle	Moderate	Moderate	Gentle	Gentle
Bank score	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.1	0.1
Bed score	0.1		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.1	0.1
Channel shape	Deepened U-shape	N/A	Widened/infilled	U-shape	Widened/infilled	Widened/infilled	U-shape	U-shape	Deepened U-shape	Widened/infilled	U-shape	U-shape	U-shape	Widened/infilled	U-shape	U-shape	U-shape	U-shape	Widened/infilled	U-shape
Bank score	1		0.5	0.8	0.5	0.5	0.8	0.8	1	0.5	0.8	0.8	0.8	0.5	0.8	0.8	0.8	0.8	0.5	0.8
Bed score	0.9		1	0.3	1	1	0.3	0.3	0.9	0.3	0.3	0.3	0.3	1	0.3	0.3	0.3	0.3	1	0.3

Bank shape Right	Compound erosional ledge	N/A	Compound depositional bench	Vertical	Concave	Concave	Vertical	Concave	Compound erosional ledge	Concave	Concave	Concave	Concave with toe sediment	Concave	Vertical	Graded	Concave	Concave	Concave	Concave
Bank score	0.7		0.1	1	0.5	0.5	1	0.5	0.7	0.5	0.5	0.5	0.3	0.5	1	0.1	0.5	0.5	0.5	0.5
Bed score	1		0.1	1	0.5	0.5	1	0.5	1	0.5	0.5	0.5	0.3	0.5	1	0.2	0.5	0.5	0.5	0.5
Bank shape Left	Vertical	N/A	Compound depositional bench	Vertical	Concave	Concave	Concave	Concave	Concave with toe sediment	Compound depositional bench	Concave	Concave	Concave with toe sediment	Vertical	Concave with toe sediment	Concave	Concave	Concave	Concave	Concave
Bank score	1		0.1	1	0.5	0.5	0.5	0.5	0.3	0.1	0.5	0.5	0.3	1	0.3	0.5	0.5	0.5	0.5	0.5
Bed score	1		0.1	1	0.5	0.5	0.5	0.5	0.3	0.1	0.5	0.5	0.3	1	0.3	0.5	0.5	0.5	0.5	0.5
Bank slope Right	Low	N/A	Low	Steep	Moderate	Moderate	Steep	Low	Steep	Low	Steep	Low	Steep	Steep	Moderate	Steep	Moderate	Steep	Moderate	Moderate
Bank score	0.3		0.3	0.8	0.5	0.5	0.8	0.3	0.8	0.3	0.8	0.3	0.8	0.8	0.5	0.8	0.5	0.8	0.5	0.5
Bed score	0.3		0.3	0.8	0.5	0.5	0.8	0.3	0.8	0.3	0.8	0.3	0.8	0.8	0.5	0.8	0.5	0.8	0.5	0.5
Bank slope Left	Moderate	N/A	Low	Steep	Moderate	Moderate	Moderate	Low	Steep	Moderate	Steep	Low	Steep	Vertical	Vertical	Low	Moderate	Steep	Moderate	Moderate
Bank score	0.5		0.3	0.8	0.5	0.5	0.5	0.3	0.8	0.5	0.8	0.3	0.8	1	1	0.3	0.5	0.8	0.5	0.5
Bed score	0.5		0.3	0.8	0.5	0.5	0.5	0.3	0.8	0.5	0.8	0.3	0.8	1	1	0.3	0.5	0.8	0.5	0.5
Bed erosion extent	0	0	0	0-25	0	0	0	0	0-25	0	0-25	N/A	N/A	N/A	N/A	N/A	0-25	0-25	N/A	0
Bank score	0	0	0	0.2	0	0	0	0	0.2	0	0.2	0	0	0	0	0	0.2	0.2	0	0
Bed score	0	0	0	0.2	0	0	0	0	0.2	0	0.2	0	0	0	0	0	0.2	0.2	0	0
Bank erosion extent Right	0-25	0	0-25	0-25	0-25	0-25	0-22	0	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0
Bank score	0.2	0	0.2	0.2	0.2	0.2	0.2	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0
Bed score	0.2	0	0.2	0.2	0.2	0.2	0.2	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0
Bank erosion extent Left	0-25	0	0-25	0-25	0-25	0-25	0	0	0-25	0	0	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0
Bank score	0.2	0	0.2	0.2	0.2	0.2	0	0	0.2	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0
Bed score	0.2	0	0.2	0.2	0.2	0.2	0	0	0.2	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0
Bank erosion type Right	Rotational slump	N/A	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Undercutting	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump
Bank erosion type Left	Rotational slump	N/A	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Undercutting	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump	Rotational slump
Channel modifications	N/A	N/A	N/A	Straightened	N/A	N/A	Dredged/Deepened	Stream crossing	N/A	N/A	N/A	N/A	N/A	N/A	Reprofiled	Dam/diversion, Rock lining, Culverts, Stream crossing	Culverts	Culverts	Culverts	Deepened/diverted
Bank score	0	0	0	1	0	0	1	0.5	0	0	0	0	0	0	0	0.9	0.3	0.3	0.3	1
Bed score	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0.9	0.6	0.6	0.6	1
Floodplain width	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Floodplain features	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bankfull channel width (m)	4	N/A	10	3	60	40	6	10	5	10	4	1	2	3	2	9	5	7	50	1
Wetted width (m)	1.5	N/A	1.5	3	60	40	0.75	1.5	0.5	10	1	0.2	0.75	1.5	1	7	2.5	1.25	50	0.3
Low-flow channel width (m)	1.5	N/A	1.5	3	60	40	0.75	1.5	0.5	1	1	0.2	0.5	1.5	1	7	2.5	0.3	0.2	0

Bankfull bank height (m)	0.5	N/A	0.4	2	0.5	1	0.75	1.2	1.5	1	2	0.3	2.5	0.5	1.25	2	1.5	0.75	0.3	0.5
Wetted depth (m)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Low-flow bank height (m)	0.1	N/A	0.1	0.5	0.1	0.1	0.2	0.2	0.05	0.1	0.2	N/A	0.2	0.15	0.2	0.2	0.1	0.05	0.1	0
Bankfull width:depth ratio	8.0	N/A	25.0	1.5	120.0	40.0	8.0	8.3	3.3	10.0	2.0	3.3	0.8	6.0	1.6	4.5	3.3	9.3	166.7	2.0
Bank score	1	N/A	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Bed score	1	N/A	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Root depth	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Riparian vegetation type	Grassland (ungrazed)	N/A	Mixed woody species	Grazed pasture	Exotic woody species	Exotic woody species	Mixed woody species	Mixed woody species	Grazed pasture	Native woody species	Native woody species	Mixed woody species	Mixed woody species	Mixed woody species	Mixed woody species	Grazed pasture	Grazed pasture	Grazed pasture	Grassland (ungrazed)	Grazed pasture
Bank score	0.8		0.1	1	0.2	0.2	0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	1	1	1	0.8	1
Bed score	0.8		0.1	1	0.2	0.2	0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	1	1	1	0.8	1
Riparian width (m)	0	N/A	10	0	60	40	10	11	0	10	4	1.5	2	1.5	1	0	0	0	50	0
Riparian continuity Right	None	N/A	Continuous	None	Continuous	Continuous	Continuous	Continuous	None	Continuous	Continuous	Continuous	Continuous	Continuous	Clumps	None	None	None	Continuous	None
Bank score	1		0	1	0	0	0	0	1	0	0	0	0	0	0.5	1	1	1	0	1
Bed score	1		0	1	0	0	0	0	1	0	0	0	0	0	0.5	1	1	1	0	1
Riparian continuity Left	None	N/A	Continuous	None	Continuous	Continuous	Continuous	Continuous	None	Continuous	Continuous	Semi-continuous	Continuous	Continuous	Continuous	None	None	None	Continuous	None
Bank score	1		0	1	0	0	0	0	1	0	0	0.2	0	0	0	1	1	1	0	1
Bed score	1		0	1	0	0	0	0	1	0	0	0.2	0	0	0	1	1	1	0	1
Dominant bar type	No bars	N/A	Infilled channel	No bars	Infilled channel	Infilled channel	No bars	No bars	No bars	Infilled channel	Infilled channel	No bars	Infilled channel	Infilled channel	No bars	Infilled channel	No bars	No bars	No bars	No bars
Bank score	1		0	1	0	0	1	1	1	0	0	1	0	0	1	0	1	1	1	1
Bed score	1		0.4	1	0.4	0.4	1	1	1	0.4	0.4	1	0.4	0.4	1	0.4	1	1	1	1
Waterfall	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cascade	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0-25	N/A	0-25	N/A	N/A	N/A	N/A	N/A
Rapid	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Steps	N/A	N/A	N/A	N/A	0-25	0-25	0-25	0-25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Riffle	N/A	N/A	0-25	N/A	26-50	26-50	26-50	N/A	N/A	N/A	N/A	N/A	0-25	N/A	0-25	N/A	N/A	N/A	N/A	N/A
Glide	N/A	N/A	N/A	76-100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Run	76-100	N/A	76-100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	26-50	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pool	Occasional	76-100	Occasional	Absent	Occasional	Occasional	Occasional	Occasional	Absent	Occasional	Occasional	Absent	Absent	Absent	Occasional	One	Absent	Absent	Occasional	Absent
Backwater	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Woody debris	No Woody debris	N/A	0-10	0-10	>20	>21	11-20	No Woody debris	No Woody debris	No Woody debris	No Woody debris	No Woody debris	>20	0-10	11 - 20	No Woody debris	No Woody debris	No Woody debris	No Woody debris	No Woody debris
Additional	Stock access	N/A	N/A	N/A	Stock access, Vegetation growth	Run-off/Overland flow	Vegetation growth	Vegetation clearance, Human access	Stock access	N/A	N/A	Run-off/Overland flow	Run-off/Overland flow		Vegetation growth	Human access, Urban development	Stock access	Run-off/Overland flow, stock access	Seepage, Urban development	Stock access
Bank score	1				1.6	0.8	0.6	0.5	1	0	0	0.8	0.8		0.6	1.6	1	1.8	1.5	1
Bed score	0.2				0.2	0.1	0	0.5	0.2	0	0	0.1	0.1		0	1.2	0.2	0.3	1	0.2

Comments			Riffles driven by woody debris		Riffles and steps driven by Willows	Riffles and steps driven by Willows	Riffles and steps driven by vegetation. Restoration planting	Steps driven by vegetation		Restoration planting	Restoration planting	Bed of channel very pugged			Planted on construction side					
Total bank erosion susceptibility score	12.2		4.6	13.9	7.3	6.7	10.3	8.3	12.5	5.5	7.7	8.2	7.6	8.1	10.0	12.2	12.4	13.8	8.8	12.1
Total bed erosion susceptibility score	11.9		6.0	11.6	7.3	7.2	9.2	7.8	11.9	6.2	7.6	7.5	6.8	9.0	9.2	11.8	11.7	12.1	9.4	11.1
Bank erosion susceptibility rating	High	N/A	Low	High	Moderate	Moderate	Moderate	Moderate	High	Low	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	High	Moderate	High
Bed erosion susceptibility rating	High	N/A	Moderate	High	Moderate	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	High	Moderate	High

3.2 Ecological values results

Table 3-2: Breakdown of ecological scores and spot sample results

Reach	Rapid habitat assessment score	Ecological value	Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Specific conductivity (µs/cm²)	pH	Time of observation
Omo_W2_1	20	Low	-	-	-	-	-	-
Omo_W2_2	27	Low	15.4	31.6	3.15	122.5	6.21	10:20
Omo_W2_4	44	High	-	-	-	-	-	-
Omo_W2_5	26	Low	15.8	74.5	7.3	2408	6.63	11:50
Omo_W2_6	58.5	High	18.8	83.2	7.7	120.4	7.73	12:10
Omo_W2_7	47.5	High	-	-	-	-	-	-
Omo_W2_8	42	High	-	-	-	-	-	-
Omo_W2_9	49	High	17.8	87.3	8.03	110.4	7.1	14:15
Omo_W2_10	37	Moderate	-	-	-	-	-	-
Omo_W2_13	14	Low	-	-	-	-	-	-
Omo_W2_11	43.5	High	-	-	-	-	-	-
Omo_W2_12	34.5	Moderate	-	-	-	-	-	-
Omo_N2_1	26.5	Low	-	-	-	-	-	-
Omo_N2_2	34	Moderate	-	-	-	-	-	-
Omo_N2_2	67	High	-	-	-	-	-	-
Omo_N2_3	48.5	High	15.1	94.9	9.4	113.3	7.57	10:00
Omo_N2_4	50	High	-	-	-	-	-	-
Omo_N2_5	22	Low	18.8	74	6.91	138.2	7.01	10:30
Omo_N2_6	51.5	High	17.8	71.4	6.78	153	7.18	
Omo_N2_7	21	Low	-	-	-	-	-	-
Omo_E1_1	36	Moderate	16.8	14.7	1.41	246.5	7.0	16:40
Omo_E1_1	47	High	-	-	-	-	-	-
Omo_E1_1	57	High	-	-	-	-	-	-
Omo_E1_2	53.5	High	-	-	-	-	-	-

Omo_E1_1	55.5	High	-	-	-	-	-	-
Omo_E2		Low	-	-	-	-	-	-
Omo_E2_1	18	Low	-	-	-	-	-	-
Omo_E2_2	18	Low	20.6	110.5	9.95	118.2	6.8	15:20
Omo_W1_1	43.5	High	-	-	-	-	-	-
Omo_W1_2	24	Low	-	-	-	-	-	-
Omo_W1_3	23.5	Low	18.5	83	7.02	27,106	6.71	9:25

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