



NZ TRANSPORT AGENCY
WAKA KOTAHI

Roads of national significance



Ara Tūhono – Pūhoi to Wellsford



Pūhoi to Warkworth

Construction Water Assessment Report
August 2013

Pūhoi to Warkworth

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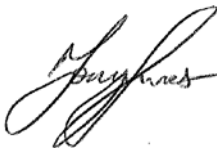
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Glossary of defined terms

Report relevant abbreviations	Definition
ACC	Auckland City Council (preceded the Auckland Council)
AEE	Assessment of Environmental Effects
AEP	Annual Exceedance Probability
ARC	Auckland Regional Council (preceded the Auckland Council)
ARI	Average Recurrence Interval
ARP:ALW	Auckland Regional Plan: Air, land and water
ARP: C	Auckland Regional Plan: Coastal
ARP: SC	Auckland Regional Plan: Sediment Control
ARPS	Auckland Regional Policy Statement
BPO	Best Practicable Option
CESCP	Construction Erosion and Sediment Control Plan
ESC	Erosion and Sediment Control
ESCP	Erosion and Sediment Control Plan
ESY	Existing Sediment Yield
FACSY	Focus Area Construction Sediment Yield
FASY	Focus Area Sediment Yield
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
MAP	Mahurangi Action Plan
NGTR	Northern Gateway Toll Road
NIWA	National Institute of Water and Atmosphere
NZTA	NZ Transport Agency
PSD	Particle size distribution
PCSY	Post construction sediment yield
RDC	Rodney District Council
RMA	Resource Management Act 1991
SCPA	Sediment control protection area
SF	Silt fence
SRP	Sediment retention pond
SSF	Super silt fence
TP10	Auckland Council Technical Publication Number 10: Stormwater Management Devices Design Guideline Manual

Report relevant abbreviations	Definition
TP90	Auckland Council Technical Publication Number 90: Erosion and Sediment Control Guidelines for Land Disturbing Activities
TSS	Total suspended solids
USLE	Universal soil loss equation

Glossary of terms

Report relevant terms	Definition
Annual Exceedance Probability Storm Event	The probability of exceeding a given storm discharge or flood level within a period of one year. For example, equivalent return period terms 100 year ARI = 100 year.
Alignment	The route or position of a proposed motorway or state highway.
Average Recurrence Interval	The average time period between rainfall or flow events which equal or exceed a given magnitude.
Auckland Council	The unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010.
Construction Runoff	Any runoff, sediment laden or otherwise, that flows as a result of the construction related activities. Typically results from rain events.
Culvert	A pipe with an inlet from a watercourse and outlet to a watercourse, designed to convey water under a specific structure (such as a road).
Earthworks	The disturbance of land surfaces by blading, contouring, ripping, moving, removing, placing or replacing soil or earth, or by excavation, or by cutting or filling operations.
Erosion control	Methods to prevent or minimise the erosion of soil, in order to minimise the adverse effects that land disturbing activities may have on a receiving environment.
Existing sediment yield	The sediment yield from the portion of the Focus Area that is not being earthworked for a given period.
Flocculation	The process whereby fine particles suspended in the water column clump together and settle. In some instances this can occur naturally, such as when fresh clay-laden flows mix with saline water, as occurs in estuaries. Flocculation can be used to promote rapid settling in sediment retention ponds by the addition of flocculating chemicals (flocculants).
Focus Area construction sediment yield	The sediment yield from the portion of the Focus Area that is being earthworked for a particular period.

Report relevant terms	Definition
Focus Area sediment yield	<p>The sediment yield from the entire Focus Area for a given period including existing (if not earthworked), construction and stabilised (or post construction) sediment yields.</p> <p>Construction Year Terminology for the Estimated Sediment Yield from a Focus Area Focus Area Sediment Yield (FASY)</p> <p>Year 1 Existing Sediment Yield (ESY) Focus Area Construction Sediment Yield (FACSY) $FASY = ESY + FACSY$</p> <p>Year 2 Focus Area Construction Sediment Yield (FACSY) $FASY = FACSY$</p> <p>Year 3 Focus Area Construction Sediment Yield (FACSY) Post Construction Sediment Yield (PCSY) $FASY = FACSY + PCSY$</p> <p>Year 4 Focus Area Construction Sediment Yield (FACSY) Post Construction Sediment Yield (PCSY) $FASY = FACSY + PCSY$</p> <p>Year 5 Post Construction Sediment Yield (PCSY) $FASY = PCSY$</p>
Intermittent stream	Any stream or part of a stream that is not a Permanent stream.
Land disturbing activity	Any disturbance to the ground surface that may result in soil erosion through the action of wind or water.
Motorway	Motorway means a motorway declared as such by the Governor-General in Council under section 138 of the PWA or under section 71 of the Government Roadings Powers Act 1989.
Nutrient load	Mass of nutrients carried in suspension in rivers and marine waters.
Permanent stream	<p>Downstream of the uppermost reach of a river or stream which meets either of the following criteria:</p> <p>(a) has continual flow; or</p> <p>(b) has natural pools having a depth at their deepest point of not less than 150 millimetres and</p> <p>a total pool surface area that is 10m² or more per 100 metres of river or stream bed length.</p> <p>The boundary between Permanent and Intermittent river or stream reaches is the uppermost qualifying pool in the uppermost qualifying reach.</p>
Post construction sediment yield	The sediment yield from the stabilised portion of the earthworked Focus Area for given period.
Project area	From the Johnstone's Hill portals in the south to Kaipara Flat Road in the north.
Sediment control	Capturing sediment that has been eroded and entrained in overland flow before it enters the receiving environment.

Report relevant terms	Definition
Sediment delivery ratio	The proportion of the soil eroded from within a catchment area that actually reaches sediment treatment controls.
Sediment generation	That sediment that is generated on the site of earthwork activity prior to treatment through any sediment retention device.
Sediment load	Mass of sediment carried in suspension within rivers and marine waters.
Sediment retention pond	A detention structure that is used during the construction phase of earthworks activity to treat any sediment laden runoff and retain sediment.
Sediment yield	That sediment which leaves the sediment retention devices and enters the receiving environment can be expressed in many ways including suspended sediment concentration or a mass load on a time basis or an aerial basis.
Shear keys	In-ground structures that improve the shearing resistance of foundation soils and usually involve deep excavations and the importation of engineered fill material.
Shear stress	Shear Stress is a measure of the force of friction from a fluid acting on a body in the path of that fluid. In the case of open channel flow, it is the force of moving water against the bed of the channel.
Stabilisation	The covering or the establishment of vegetation on, exposed bare earth (e.g. application of mulch, covering with geotextile material, topsoil and seeding or hydro-seeding).
Stormwater	Water from rain events that flows from the completed areas (both pervious and impervious) of the motorway after the construction period.
Stormwater pond	A stormwater management device which detains runoff, typically from a design storm, and then discharges it, usually at the pre-development peak discharge rate. It can also provide water quality treatment primarily through sedimentation. A stormwater pond can either be a dry pond which is normally dry between storm events, or a wet pond which has a standing pool of water.
Project	The Pūhoi to Warkworth section of the Ara Tuhono – Pūhoi to Wellsford Roads of National Significance project.
Wetland	Permanent vegetated stormwater treatment device designed to remove a range of contaminants, providing superior water quality treatment to wet ponds with increased filtering and biological treatment performance.

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1. Introduction

This report provides an assessment of the construction water effects of the NZ Transport Agency's Ara Tūhono Pūhoi to Wellsford Road of National Significance (RoNS) Pūhoi to Warkworth Section (the Project).

Purpose and Scope - The purpose and scope of this Report is to:

- Identify the construction related water management issues for the Project;
- Identify the construction water management principles for the Project;
- Describe the environmental management issues and Erosion and Sediment Control (ESC) measures for the construction process;
- Develop construction water management methodologies for key construction activities;
- Assess environmental risks associated with sediment yield and concentrations with assistance of the following modelling tools: GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), and the USLE (Universal Soil Loss Equation); and
- Identify monitoring procedures.

Construction Zones - To allow a conceptual construction programme to be developed, the Project has been divided into eleven construction zones. Earthworks activities will be required within nine of the construction zones listed below:

- Zone 1 – From the Johnstone's Hill tunnels to the south end of the Okahu Viaduct;
- Zone 3 – From Billings Road to Pūhoi Road;
- Zone 5 – From the northern end of the Pūhoi Viaduct to Watson Road;
- Zone 6B – Between Hikauae and Schedewys Viaducts;
- Zone 7A - From the northern end of Schedewys Viaduct to south of Moirs Hill Road;
- Zone 7B – From south of Moirs Hill Road to the southern end of the Perry Road Viaduct;
- Zone 9A – From the northern end of the Perry Road Viaduct to the southern end of the Kauri Eco Viaduct;
- Zone 9C – From the northern end of the Kauri Eco Viaduct to the southern end of the Woodcocks Road Viaduct; and
- Zone 11 – From the northern end of the Woodcocks Road Viaduct to the Warkworth Interchange.

These nine construction zones form the basis of our assessment of erosion and sediment control and water quality.

Erosion and sediment control Focus Areas - For the purposes of our assessment, we have identified two Focus Areas: a 'Hill Focus Area' and a 'Flat Focus Area'. Detailed methodologies and management practices were assessed and applied in these areas. The results from our assessment of these two Focus Areas will be extrapolated through the Project and the associated assessment.

1.1 Purpose and scope of this report

This Construction Water Assessment Report (this Report) forms part of a suite of technical reports prepared for the NZ Transport Agency's Ara Tūhono Pūhoi to Wellsford Road of National Significance (RoNS) Pūhoi to Warkworth Section (the Project). Its purpose is to inform the Assessment of Environmental Effects (AEE) and to support the resource consent applications and Notices of Requirement for the Project.

The indicative alignment shown on the Project drawings has been developed through a series of multi-disciplinary specialist studies and refinement. A NZTA scheme assessment phase was completed in 2011, and further design changes have been adopted throughout the AEE assessment process for the Project in response to a range of construction and environmental considerations.

It is anticipated that the final alignment for the Project will be refined and confirmed at the detailed design stage through conditions and outline plans of works. For that reason, this assessment has addressed the actual and potential effects arising from the indicative alignment, and covers the proposed designation boundary area. Except as noted in this Report:

- We consider that the sites we have selected for surveys, testing and analysis are generally representative of all areas within the proposed designation boundary; and
- The recommendations we propose to mitigate adverse effects are applicable to other similar areas within the proposed designation boundary, subject to confirmation of their suitability at the detailed design stage

In particular, this Report assesses the effects of construction-related water management (including the management of erosion and sedimentation) on the receiving environment during the construction stage of the Project.

This Report describes the methods and practices to be implemented to minimise environmental effects and was written by Graeme Ridley of Ridley Dunphy Environmental Ltd and Michelle Sands, Tony Cain and Roanna Salunga from the Further North Alliance Team.

The scope of the work carried out to prepare this Report is as follows:

- Identify the construction-related water management issues for the Project;
- Identify the construction water management principles for the Project;
- Describe the environmental management issues and solutions including Erosion and Sediment Control (ESC) measures for the construction process;
- Develop construction water management methodologies for key construction activities;
- Assess environmental risks associated with sediment yield with assistance of the following modelling tools: GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), and the USLE (Universal Soil Loss Equation); and
- Identify monitoring procedures.

The structure and content of this Report is as follows:

- **Section 1** (this Section) – We describe the Project and the content of this Report.
- **Section 2** – We discuss the statutory and non-statutory framework relevant to the Project, particularly as it relates to ESC and water quality.
- **Section 3** – We describe the existing environment and the factors that affect erosion and subsequent sedimentation, such as climate and rainfall, topography, geology and construction staging.
- **Section 4** – We discuss the erosion and sediment generation processes. This section also highlights the various ESC measures and practices required to reduce erosion and increase capture of sediment generated during construction of the Project.
- **Section 5** – We discuss the ESC design philosophy and principles adopted for the Project.
- **Section 6** – We discuss the specific ESC controls and practices required to plan, design, operate, maintain and decommission ESC control devices during the Project construction period.
- **Section 7** – We describe the sediment generation and yield modelling process and the associated results including sediment yield extrapolation. We also outline the water quality analysis and interpretation. We also discuss the freshwater and coastal sediment transport and deposition process.
- **Section 8** – We discuss the water quality sampling and adaptive monitoring programme that will be carried out during construction of the Project and how this sampling data will be used to manage construction activity.
- **Section 9** – We assess the environmental effects of construction related runoff from the Project on the receiving environment, with focus on the statutory tests that apply.
- **Section 10** – We consider the various assessments and present our recommendations and conclusions made on the results of those assessments. The recommendations detailed in this section highlight the most effective physical measures and site management practices that shall be put in place as part of the Project to eliminate, reduce and mitigate the effects of sediment entering the receiving environment.
- **Section 11** – Contains a list of documents used and referred to in the preparation of this Report.

1.2 Project description

This Project description provides some context for this assessment. Sections 5 and 6 of the Assessment of Environment Effects (Volume 2) further describe the construction and operational aspects of the Project and should be relied upon as a full description of the Project.

The Project realigns the existing SH1 between the Northern Gateway Toll Road (NGTR) at the Johnstone's Hill tunnels and just north of Warkworth. The alignment will bypass Warkworth on the western side and tie into the existing SH1 north of Warkworth. It will be a total of 18.5km in length. The upgrade will be a new four-lane dual carriageway road, designed and constructed to motorway standards and the NZTA RoNS standards.

1.3 Project features

Subject to further refinements at the detailed design stage, key features of the Project based on the indicative alignment and proposed designation boundary shown on the Project drawings are:

- Four-lane dual carriageway (two lanes in each direction with a median and barrier dividing oncoming lanes);
- A connection with the existing NGTR at the Project's southern extent;
- A half diamond interchange providing a northbound off-ramp at Pūhoi Road and a southbound on-ramp from existing SH1 just south of Pūhoi;
- A western bypass of Warkworth;
- A roundabout at the Project's northern extent, just south of Kaipara Flats Road to tie-in to the existing SH1 north of Warkworth and provide connections north to Wellsford and Whangarei;
- Construction of seven large viaducts, five bridges (largely underpasses or overpasses and one flood bridge), and 40 culverts in two drainage catchments: the Pūhoi River catchment and the Mahurangi River catchment;
- A predicted volume of earthworks being approximately 8M m³ cut and 6.2M m³ fill within a proposed designation area of approximately 189ha earthworks; and
- Removal of approximately 83.5ha of trees, comprising predominantly plantation pine and approximately 4ha of native bush.

The existing single northbound lane from Waiwera Viaduct and through the tunnel at Johnstone's Hill will be remarked to be two lanes. This design fully realises the design potential of the Johnstone's Hill tunnels.

The current southbound tie-in from the existing SH1 to the Hibiscus Coast Highway will be remarked to provide two-way traffic (northbound and southbound), maintaining an alternative route to the NGTR. The existing northbound tie-in will be closed to public traffic as it will no longer be necessary.

1.4 Interchanges and tie-in points

The Project includes one main interchange and two tie-in points to the existing SH1, namely:

- The Pūhoi Interchange;
- Southern tie-in where the alignment will connect with the existing NGTR; and
- Northern tie-in where the alignment will terminate at a roundabout providing a connection with the existing SH1, just south of Kaipara Flats Road north of Warkworth.

1.5 Route description by Sector

For assessment and communication purposes, the Project has been split into six sectors, as shown in Figure 1 below:

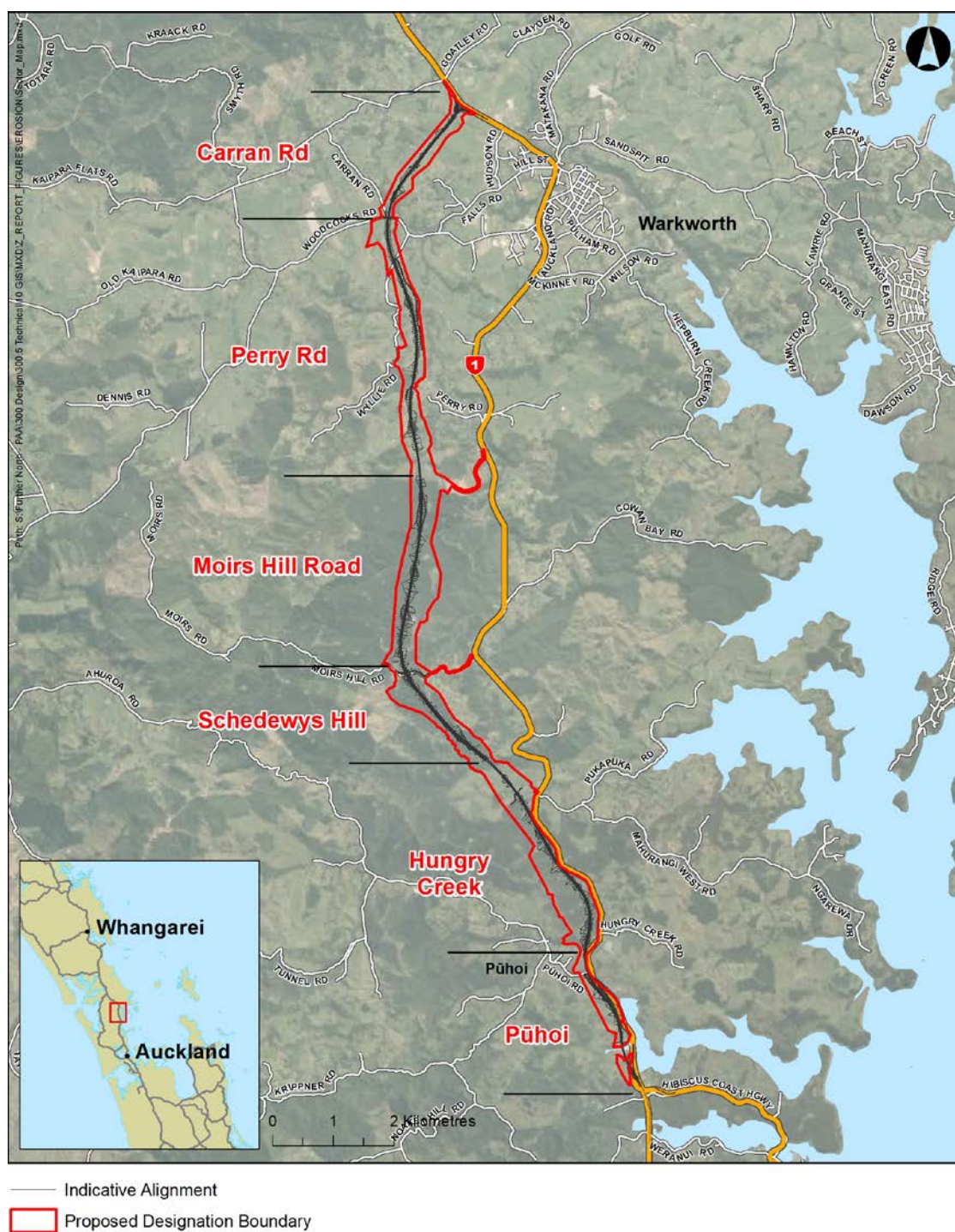


Figure 1: Project Sectors (Further North, 2013)

1.6 Construction zones

Conceptual construction for the Project is split into construction zones as shown in Figure 2 below). The zones that are relevant to the earthworks construction activities are:

- Zone 1 – From the Johnstone's Hill tunnels to the south end of the Okahu Viaduct;
- Zone 3 – From Billings Road to Pūhoi Road;
- Zone 5 – From the northern end of the Pūhoi Viaduct to Watson Road;
- Zone 6B – Between Hikauae and Schedewys Viaducts;
- Zone 7A - From the northern end of Schedewys Viaduct to south of Moirs Hill Road;
- Zone 7B – From south of Moirs Hill Road to the southern end of the Perry Road Viaduct;
- Zone 9A – From the northern end of the Perry Road Viaduct to the southern end of the Kauri Eco Viaduct;
- Zone 9C – From the northern end of the Kauri Eco Viaduct to the southern end of the Woodcocks Road Viaduct; and
- Zone 11 – From the northern end of the Woodcocks Road Viaduct to the Warkworth Interchange.

The other construction zones are related primarily to the construction of structures and are as follows:

- Zone 2 – The Okahu Creek Viaduct;
- Zone 4 – The Pūhoi River Viaduct;
- Zone 6A – The Hikauae Viaduct;
- Zone 6C – The Schedewys Hill Viaduct;
- Zone 8 – The Perry Road Viaduct;
- Zone 9B – The Kauri Eco Viaduct; and
- Zone 10 – The Woodcocks Road Viaduct.



1.7 Erosion and sediment control Focus Areas

Following a review of the Project, associated site visits and discussions with technical specialists in the Project team, we determined that from an ESC perspective, the Project can be classified into two distinct types of terrain as follows:

- Hill Country – including the prominent landforms of Pūhoi, Schedewys Hill and Moirs Hill; and
- Flat Country – including the relatively flat areas from Perry Road to Warkworth along the Mahurangi River Right Branch.

To assess environmental effects related to erosion and sedimentation, two areas of the Project, referred to as Focus Areas, were selected to represent the Hill Country and Flat Country terrain types encountered on the Project as follows:

- Flat Focus Area (Perry Road Sector) – Comprises approximately 35.7 hectares and is considered to be representative of the Flat Country within the Project area and runs from Woodcocks Road to Perry Road Viaduct (CH 49,250 to CH 53,150) within the Perry Road Sector. This Focus Area is referenced within this Report as the 'Flat Focus Area'; and
- Hill Focus Area (Moirs Hill Road Sector) – Comprises approximately 54.2 hectares and is considered to be representative of the Hill Country within the Project area and runs from the Perry Road Viaduct to Moirs Hill Road (CH 53,450 to CH 56,850) within the Moirs Hill Road Sector. This Focus Area is referenced within this Report as the 'Hill Focus Area'.

The two Focus Areas are shown in Figure 3 and represent the two terrain types of the overall construction for the Project. The total length of the two Focus Areas makes up approximately 40% of the Project length. Conceptual construction methodologies, relating to erosion and sediment control, for these Focus Areas can be found in Section 6 of this Report.

As explained in Section 3 of this Report, we consider the soil properties, geology, topography, ground slopes and climate in the two Focus Areas to be representative of those for the remainder of the Project. This representativeness has provided us with the confidence to confirm that we do not need a specific Focus Area within the Pūhoi Catchment and that the extrapolation of the construction methodologies and the results of the associated sediment yield calculations to the Pūhoi, Hungry Creek and Schedewys Hill Project sectors is appropriate.

We have therefore been able to assess the effects of the construction for the entire Project by applying appropriate scaling factors to the modelled results. We also assess that the NGTR (Northern Gateway Toll Road) has similar conditions to the Project whereby learnings can be directly applied. These learnings include direct knowledge and discussions with personnel involved with the NGTR, including those of the Further North Alliance Team.

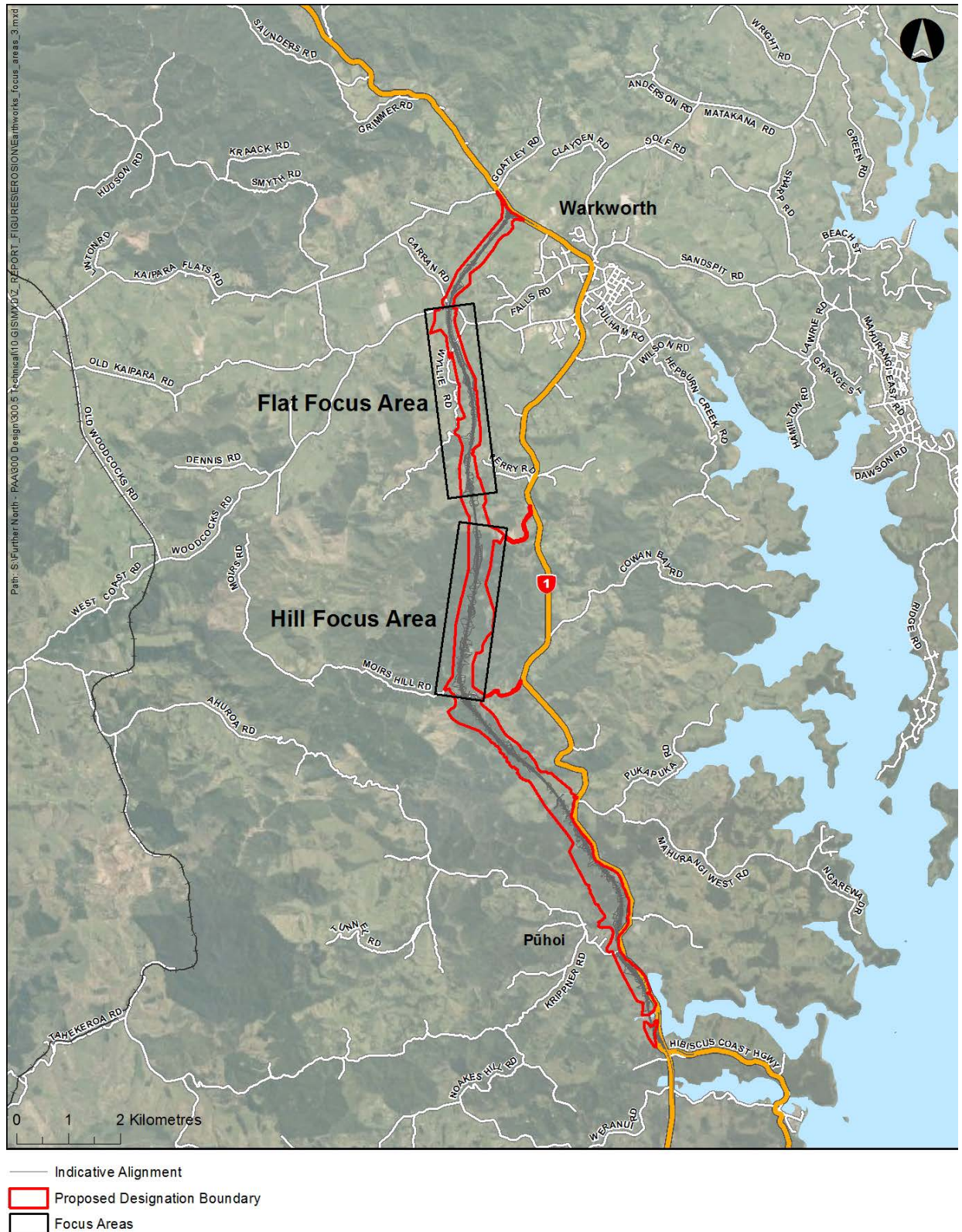


Figure 3: Earthwork Focus Areas (Further North, 2013)

1.8 Construction sequencing

A conceptual construction programme for the Project has been developed and is reported in Section 6 of the AEE and further comment in relation to ESC is provided in Section 6 of this Report.

From an ESC perspective, the focus for the construction sequence is centred on the Flat Focus Area and the Hill Focus Area, as discussed in Section 1.7 of this Report. We consider this construction methodology and sequence to be a practical approach to achieving the associated bulk earthworks operations within these locations.

The specific cut and fill locations and associated catchment boundaries will be finalised at a later date. For our assessment we have applied a conceptual construction sequence, which represents a typical approach for the Focus Areas. This construction sequence includes the disposal of surplus fill within identified spoil site locations.

We acknowledge that the construction sequence that we have used for the purposes of the assessment of the Focus Areas, and associated sediment yield calculations, has been amended as the design of the Project has progressed.

When considered from an ESC perspective, the spreadsheets within Water Assessment Factual Report 1 – Estimating Sediment Yield using USLE and Sediment Control Devices (WAFR 1) adequately represent a 5 year and a 10 year construction programme. We consider these timeframes to be reflective of construction period options, which include providing a longer construction period whereby exposed open areas of earthworks can be reduced. The results of the sediment yield modelling of these scenarios are discussed in Section 7 of this Report.

Limiting the extent of open areas of earthworks at any one time within specific catchment areas will be a key ESC management tool for the Project. We have calculated sediment yields for both the 5 and 10 year scenarios and based on the construction sequencing have recommended open area limitations. These open area limitations (discussed and reported on in Section 7 of this Report) are therefore based on a practical construction sequence with knowledge of sediment yields and with flexibility to allow works to be undertaken within these appropriate limits.

1.9 Construction discharge locations

Based on the conceptual construction methodology and sequencing for the Flat Focus Area and the Hill Focus Area, we have developed conceptual ESCPs (Erosion and Sediment Control Plans), which demonstrate the ability to install appropriate ESC devices, which we have also confirmed through site visits.

While we acknowledge that the ESCPs (and associated construction methodology) are conceptual only, we have investigated the locations of the associated sediment retention devices as part of the development of this Report and have viewed the proposed discharge locations. The discharge locations from the sediment control devices for the two Focus Areas are shown on Drawings ES-001 to ES-025.

From an overview perspective, all construction related runoff discharges are either to a land environment or direct to freshwater systems. We consider discharges to land to be beneficial in

that a land-based buffer zone will provide a 'polishing' effect of the discharged runoff. Where discharges are direct to freshwater systems, to minimise erosion of the stream bank and bed at that point, the outlet will be protected with geotextile and riprap material in the immediate vicinity of the outlet. Drawing ES-151 shows a typical detail of a sediment retention pond.

As confirmed within the Freshwater Ecology Assessment Report there are no specific freshwater environments where discharges cannot occur due to ecological constraints. Discharges into the Coastal Marine Area (CMA) are limited to those associated with the Okahu Creek works. These discharge locations are associated with the indicative alignment.

Table 1 lists the SRPs (Sediment Retention Ponds) discharging to permanent streams (as defined in the Freshwater Ecology Assessment Report) and identifies those discharging at least 50m from a permanent stream. These locations are shown in Drawings ES-001 to ES-025. These discharge locations are associated with the indicative alignment.

Table 1: Construction related discharges and locations within the two Focus Areas

Focus Area	Indicative alignment discharge point location (chainage)	Permanent stream ecological reference (as defined in Freshwater Ecology Assessment Report)	Discharging to land (Outlet >50 m from permanent stream)
Hill Focus Area	56700	M13	No
	56200	M13a	No
	56100	M13b	Yes
	55700	M13c	Yes
	54950	M15	No
	54800	M15	No
	54700R	M15	Yes
	54700L	M15	No
	54600	M15	No
	53800R	M15a	Yes
	53500	M16	No
Flat Focus Area	53000L	M17	No
	52400	M19	Yes
	51550	M19b	No
	51700	M19b	No
	51400R	M19c	No

Focus Area	Indicative alignment discharge point location (chainage)	Permanent stream ecological reference (as defined in Freshwater Ecology Assessment Report)	Discharging to land (Outlet >50 m from permanent stream)
	51400L	M19c	No
	52200	M19/M18	Yes
	52000	M19/M18	Yes
	51100R	M21a	No
	51100L	M21a	No
	50800	M21b	No
	49600	M22	No
	49500	M22	No
	49400	M22	Yes
	50900	PA900a	No

1.10 Associated reports

The Project's water-associated assessments of effects are presented in four reports. The four reports are titled as follows:

- Construction Water Assessment Report;
- Operational Water Assessment Report;
- Freshwater Ecology Assessment Report; and
- Marine Ecology Assessment Report.

This Construction Water Assessment Report is authored by the following discipline specialists:

- Hydrology;
- Erosion and sediment control;
- Stormwater (for temporary structures);
- Freshwater quality; and
- Marine water quality.

The Fresh Water and Marine Ecologists have contributed to the assessment reports by identification of sensitive environments and requirements for their own assessments.

The Construction and Operational Water Assessment Reports provide a description of the potential adverse effects created by the Project. These assessment reports document recommendations for mitigation measures and practices to avoid, mitigate or remedy the potential adverse effects of the Project on the environment. These reports assess the residual effects (after applying the recommended mitigation measures and practices), including a comparison between the existing (pre-development) conditions with the anticipated residual construction / operational conditions. The Assessment Reports culminate in recommendations for consent conditions / frameworks to ensure the Project will be compliant with the RMA and other statutory requirements.

The Construction and Operational Water Assessment Reports summarise the key technical information and assumptions on which the assessments are based, and cross reference other discipline Project Technical Reports where appropriate. Additional Water Assessment Factual Reports contain further detail and can be provided on request to the Further North Alliance.

The Freshwater and Marine Ecology Assessment Reports assess the residual effect, informed by the Construction and Operational Water Assessment Reports, to the respective environment. The Ecological Assessments consider the anticipated effects generated in both the construction and operational phases of the Project.

The pertinent information from the four water Assessment Reports for the Project has been assimilated into the AEE for the Project.

When reading the Assessment Reports the reader is encouraged to read the summary boxes at the start of each section. The summary boxes provide a snapshot of what is included in that section and, read in succession, will provide a comprehensive overview of the assessment.

We also produced a number of Water Assessment Factual Reports (WAFRs) to supplement and inform the preparation of this Report. These WAFRs contain detailed calculations, design details and supporting information. These WAFRs do not form part of the application documentation for the Project. The WAFRs that are relevant to this Report are as follows:

- Water Assessment Factual Report 1 Estimating Sediment Yield using USLE and Sizing of Sediment Control Devices (WAFR 1);
- Water Assessment Factual Report 2 Tests for Chemical Treatment (WAFR 2);
- Water Assessment Factual Report 3 Estimates of Construction Sediment yields using the GLEAMS Model (WAFR 3);
- Water Assessment Factual Report 4 Water Quality Monitoring Report (WAFR 4); and
- Water Assessment Factual Report 5 Coastal Processes Monitoring Report (WAFR 5).

Where we feel it is necessary to explain the context of our assessment in this Report, we have made references to the other Assessments and WAFRs produced as part of the overall assessment associated with the Project.

The reporting structure, showing the associated Assessment Reports and WAFRs is shown below in Figure 4.

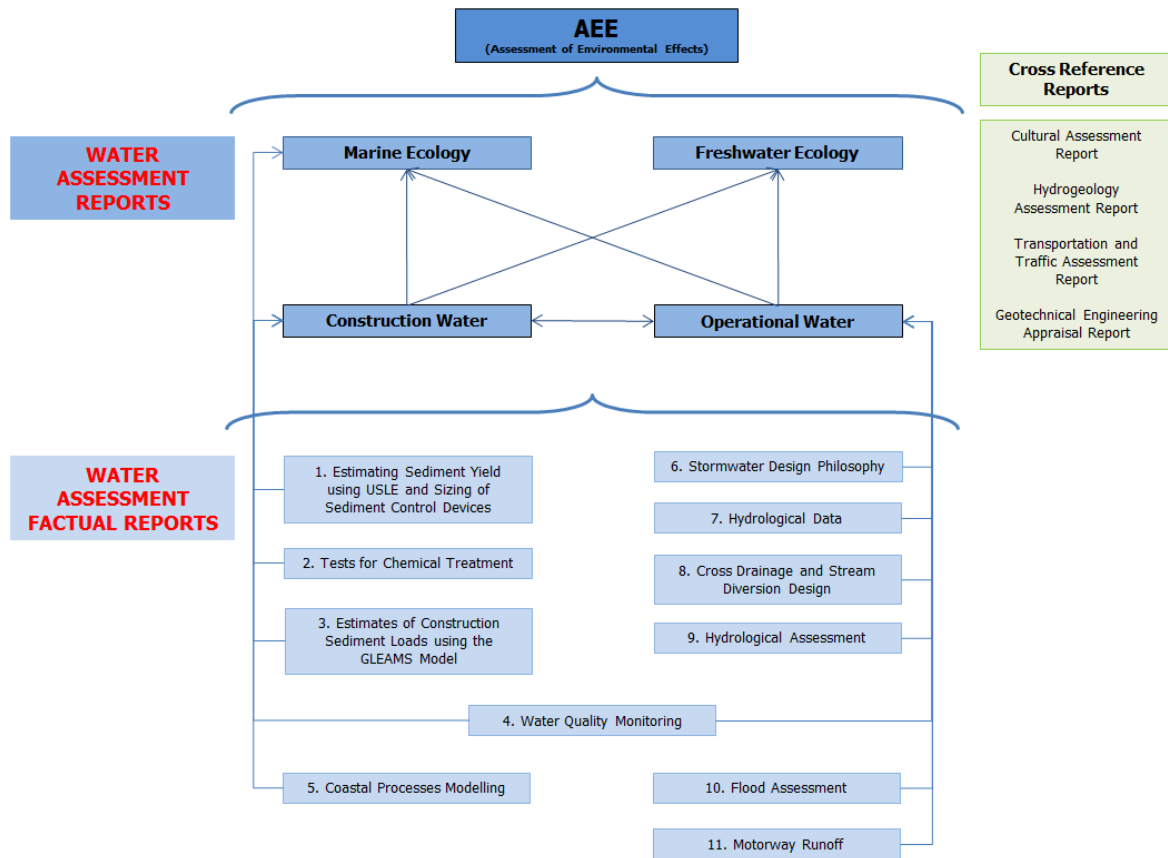


Figure 4: Overall AEE reporting framework

2. Statutory and non-statutory context and technical framework

Statutory framework

The relevant statutory framework relating to the project is set out as follows:

Resource Management Act 1991 (RMA) - The purpose and principles of the RMA are set out in Sections 5 to 8 of the Act. The particular sections of the RMA relevant to the project are:

- Section 7(c) - Maintenance and enhancement of amenity values;
- Section 7(f) - Maintenance and enhancement of the quality of the environment;
- Section 15 (1) - Sets restrictions on discharges to water; and
- Section 107 - Sets restrictions on the granting of discharge permits.

The National Policy Statement for Freshwater Management 2011 (NPSFM) - The NPSFM contains objectives and policies relating to water quality.

Auckland Council - Auckland Council has a number of Policies and Plans in place that are relevant to the project as follows:

- The Auckland Council Regional Policy Statement (RPS) – This Plan contains objectives and policies relating to water quality;
- The Auckland Regional Plan: Air, Land and Water Plan (ARP:ALW) - This Plan manages issues around water quality in the region;
- The Auckland Regional Plan: Sediment Control (ARP:SC) - This Plan addresses the issue of sediment discharge, and defines mechanisms for avoiding, remedying or mitigating any adverse effect on the environment due to sediment discharge from bare earth surfaces; and
- The Auckland Regional Plan: Coastal (ARP:C) – This Plan sets out objectives and policies relating to the discharge of contaminants in the coastal area.

Non-statutory framework

New Zealand Transport Agency (NZTA) - The NZTA has published an Environment Plan, which is a non-statutory plan that contains objectives relating to water resources.

Mahurangi Action Plan (MAP) - The Mahurangi Action Plan is a non-statutory plan for the Mahurangi River and estuary catchment that was established and adopted by the former Rodney District Council among others. The plan contains objectives and priority actions for 2010-2016.

Technical Publication No. 90. Erosion and Sediment Control: Guidelines for Land Disturbing Activities (TP90), Auckland Council – TP90 provides information on the appropriate use, design and construction of ESC practices for the Auckland region.

Erosion and Sediment Control Standard for State Highway Infrastructure (NZTA Draft Standard) – the NZTA is developing a standard for State highway infrastructure. A draft document has been prepared for comment (dated August 2010) and is currently being finalised.

2.1 Statutory framework

2.1.1 Resource Management Act 1991

The Resource Management Act 1991 (RMA) regulates activities that may affect the environment, including stormwater discharges. Sections 14 and 15 are the governing sections of the RMA in relation to use of and discharges to water.

The purpose and principles of the RMA are set out in sections 5 to 8 of that Act. Of particular relevance to this assessment of effects of discharges to water are sections 5(1) and 5(2).

Section 7 of the RMA requires consent authorities to have particular regard to those matters listed in the section. In the case of discharges to water from this Project, we consider the following matters to be relevant:

- Maintenance and enhancement of amenity values (Section 7(c)); and
- Maintenance and enhancement of the quality of the environment (Section 7(f)).

In the context of this assessment, amenity values may be affected by discharges of sediment-laden water during construction. The quality of the water environment is primarily defined by effects on the life supporting capacity of the water and its ability to provide for uses of the water.

Section 107 of the RMA places restrictions on the grant of certain discharge permits.

2.1.2 National Policy Statement for Freshwater Management

The National Policy Statement for Freshwater Management 2011 (NPSFW) (MfE 2011) contains objectives and policies relating to water quality. There are no freshwater quality limits determined for the freshwater bodies within the Project area.

2.1.3 National Environmental Standard for Sources of Human Drinking Water

The National Environmental Standard for Sources of Human Drinking Water 2007 applies only to water sources *before* they are abstracted by a drinking water treatment plant. After the water treatment plant, Ministry of Health legislation and standards apply.

2.1.4 Regional Policy Statement

The Auckland Regional Policy Statement (ARPS) (Auckland Regional Council, 1999) sets out the high level issues and objectives for the region, including a chapter on water quality that references some of the values attributed to water in the region.

2.1.5 Auckland Regional Plans

The primary Auckland Council statutory management tools for water quality, land disturbing activities, erosion, sediment generation and deposition are:

- **The Auckland Regional Plan: Sediment Control (ARP:SC)** which addresses earthworks, vegetation removal and/or clearance (such as forest harvesting), roading/tracking/trenching, and quarries.

The ARP:SC regulates land disturbing activities and makes a distinction between general land and 'Sediment Control Protection Areas' (SCPAs). It identifies (in Section 5.5.2 of the ARP:SC) SCPAs which the Council considers to be particularly vulnerable to impacts of the discharge of sediment, as those areas 100 m landward of the Coastal Marine Area or 50 m landward of the edge of a watercourse or wetland of 1,000 m² or more.

The earthworks required to construct the Project will exceed these thresholds and resource consent will be required. For completeness purposes we note that Council has restricted its discretion with respect to managing erosion and sediment control to the following matters:

- Techniques used to restrict or control sediment being transported from the site and the effects or impacts of sediment on water quality from the techniques chosen, including the practicality and efficiency of the proposed control measures;
- The proportion of the catchment which is exposed;
- The proximity of the operation to the receiving environment;
- The concentration and volume of any sediment that may be discharged;
- The time during which the bare earth surface is exposed;
- The time of year when the activity is undertaken;
- The duration of the consent; and
- Monitoring the volume and concentration of any sediment that may be discharged.

We also note that while consent is required for the earthworks activity itself, the discharge from those associated earthworks is a permitted activity in accordance with Rule 5.5.1 of the ARP:SC. Damming or diversion of water in respect of the control of sediment laden runoff is also permitted under Rule 5.5.3 of the ARP:SC.

- **The Auckland Regional Plan: Coastal (ARP:C)** (Auckland Council, 2011) which sets out objectives and policies relating to the discharge of contaminants. The effects of discharges from the Project can pass into the coastal zone hence the ARP:C is relevant to the Project.
- **The Auckland Regional Plan: Air, Land and Water (ARP:ALW)** (Auckland Council, 2012a) which manages issues relating to water quality in the region.

The ARP:ALW sets out water quality related objectives, policies and rules relevant to the Project activities. These include stormwater discharges and works in the beds of rivers. General high level water quality objectives are set out in Objective 5.3.1 of the ARP:ALW along with general policies relating to this objective.

Chapter 7 of the ARP:ALW covers the beds of lakes and rivers and the diversion of water. We consider Objectives 7.3.1 and 7.3.2 (which set out the general direction for in river works) and General Policies 7.4.3 and 7.4.9 to be relevant to the potential effects of the Project.

2.2 Non-statutory framework

2.2.1 Auckland Council guiding documents

Auckland Council has a specific earthworks programme which includes a number of guidance documents of relevance to erosion and sediment control and this Project, including:

- **Technical Publication No. 90. Erosion and Sediment Control: Guidelines for Land Disturbing Activities (TP90), Auckland Council** which provides information on the appropriate use, design and construction of ESC practices for the Auckland region. We consider TP90 represents industry best practice and generally provides the accepted design criteria for ESC measures. The key principles of TP90 are included in Appendix A of this Report.

Other relevant Auckland Council guidance material includes draft chemical treatment guidelines, specific ESC fact sheets and many technical reports related to management and effects of sedimentation and works within a watercourse. These documents have all been reviewed and relevant information obtained in the development of this Report.

2.2.2 NZTA guiding documents

The NZTA has several guiding documents in relation to ESC, including:

- **Erosion and Sediment Control Standard for State Highway Infrastructure (NZTA Draft Standard)** – the NZTA is developing a standard for State highway infrastructure. A draft document has been prepared for comment (dated August 2010) and is currently being finalised after submissions closed in July 2011. The key principles of the NZTA Draft Standard are included in Appendix A of this Report.
- **NZTA Environmental Plan 2008** – A series of ESC objectives for roading projects is contained in this plan. The key erosion and sediment management objectives are:
 - Ensure construction and maintenance activities avoid, remedy or mitigate effects of soil erosion, sediment run-off and sediment deposition;
 - Identify areas susceptible to erosion and sediment deposition and implement ESC measures appropriate to each situation with particular emphasis on high-risk areas; and
 - Use bio-engineering and low-impact design practices where practicable.

The NZTA Environmental Plan also contains the following objectives relating to water resources:

- W1 Ensure run-off from State highways complies with RMA requirements;
- W2 Limit the adverse effects of run-off from State highways on sensitive receiving environments; and
- W3 Ensure stormwater treatment devices on the network are effective.

2.2.3 Mahurangi Action Plan 2010

The Mahurangi Action Plan (MAP) is an Auckland Council strategic plan for the Mahurangi Catchment (2010-2030). It has a vision of maintaining a healthy Mahurangi River and Harbour. The MAP identifies key values and issues including:

- Sedimentation of the Harbour environment;
- Maintaining a Commercial Asset; and
- Natural Heritage, Biodiversity and Ecological Values.

The MAP contains objectives and priority actions for 2010-2016. Table 2 below describes those objectives and actions that are relevant to sedimentation and water quality.

Table 2: Priority actions from the Mahurangi Action Plan

Objective	Action for MAP
Sediment generation is reduced	<p>Develop a riparian management programme (including retiring, fencing and replanting of riparian and foreshore corridors) including prioritising and funding.</p> <p>Plant stream margins, and fence where adjoining land will be grazed.</p> <p>Educate on best practice methods of development and land-use (e.g. roading, farming, forestry); simple stormwater solutions (green engineering and Low Impact Design (LID) as techniques to reduce the impact of stormwater from heavy rainfall/ storm events); balancing economic return and environmental effects of land-use; and promote engagement with land user groups to promote less sediment generating forms of land-use (e.g. farm forestry, indigenous forestry, permaculture groups and Federated Farmers.</p>
Vegetation cover is maintained and increased	<p>Plant the steeper hills in indigenous forest (either permanently or for commercial harvest) to increase resilience of the land and reduce sediment generation.</p>
Water quality is safe for commercial and recreational activities	<p>Continue assessment of sources, concentrations and effects of principal contaminants and non-point source.</p> <p>Improve water quality for the oyster farms.</p>

2.3 Assessment criteria for the Project

Table 3 below outlines the assessment matters from the RMA, ARP:SC, ARP:ALW and the District Plan that need to be considered for the construction activity associated with this Project.

Table 3: Assessment Criteria/ Consideration

Matter / consideration	Explanation
Erosion and Sediment Control and Environmental Management for Land Disturbing Activities including streamworks and vegetation removal. Best practicable option (BPO) approach	<p>Have regard to the applicant's reason for the proposed choice and any possible alternative methods of discharge, including discharge into other receiving environments (RMA s105).</p> <p>Avoid remedy or mitigate adverse effects of the receiving environments from the discharge of sediment and construction related contaminants.</p> <p>Consider proposed choice of approach and associated measures and methodologies employed.</p> <p>Consider monitoring programmes to measure effectiveness of measures and methodologies</p> <p>Consider overall effects of construction related discharges on the freshwater and marine receiving environments from the discharge of sediment and other construction related contaminants.</p>
Flooding	Not give rise to flooding of adjacent land or exacerbate existing flooding.
Aesthetics and odour	<p>RMA Section 107. After reasonable mixing, the contaminant or water discharged shall not give rise to any of the following effects in the receiving waters:</p> <p>(c) the production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials;</p> <p>(d) any conspicuous change in the colour or visual clarity; and</p> <p>(e) any emission of objectionable odour.</p>
Water Users	<p>The rendering of freshwater unsuitable for consumption by farm animals (RMA Section 107).</p> <p>Minimise effects on other water users. Water quality is safe for commercial and recreational activities (MAP).</p>
Human Impacts	<p>NES for sources of human drinking water 2007</p> <p>A regional council must not grant a water permit or discharge permit for an activity that will occur upstream of an abstraction point where the drinking water concerned meets the health quality criteria if the activity is likely to:</p> <p>(a) introduce or increase the concentration of any determinands in the drinking water, so that, after existing treatment, it no longer meets the health quality criteria; or</p> <p>(b) introduce or increase the concentration of any aesthetic determinands in the drinking water so that, after existing treatment, it contains aesthetic determinands at values exceeding the guideline values.</p>

3. Existing environment

A number of factors that form part of the existing environment affect erosion and subsequent sedimentation. These factors include rainfall, topography, geology and water quality, all of which require full consideration through the Project construction period.

The Project area is characterised by steep topography with 45% of the earthworks area identified as having slopes equal to or greater than 15 degrees. From an assessment perspective the Project is considered as Hill Country and Flat Country.

The geology between these two land types differs and the dominance of the Pakiri Formation is noted within the Hill Country. The steep terrain along much of the Project alignment results in much of the overlying soils being either unstable or highly susceptible to erosion when exposed to certain climatic and ground cover conditions, and the underlying Pakiri Formation allows for the more competent rock to be worked over the winter period.

Forestry, pasture and indigenous forestry are the main land-uses throughout both the Mahurangi and Pūhoi catchments.

Sediment deposition is a key environmental issue in the Mahurangi estuary and harbour with existing pre-construction sediment deposition from surrounding catchment land-uses currently impacting upon the estuary.

Various studies and existing Auckland Council data indicate that the Mahurangi catchment water quality is generally good with slightly elevated suspended solid levels, turbidity and phosphorus with metals and hydrocarbon concentrations considered to be low.

Both catchments support a range of values and are considered suitable for a range of uses; however, we consider that they are sensitive to further additions of sediment and nutrients.

3.1 Rainfall

The Project area receives greater annual rainfall than the Auckland Isthmus to the south as determined from the rainfall data from TP108 (ARC, 1999), the High Intensity Rainfall Data System (HIRDS) V3 (NIWA, 2013), and rainfall records from Auckland Council.

Table 4 below provides an overview of the rainfall data for the Project area and demonstrates that there is spatial distribution of rainfall along the route. From review of the rainfall data it can be seen that rainfall within the Mahurangi Catchment typically exceeds that of the Pūhoi Catchment by approximately 10%.

From an ESC perspective, we do not consider this difference in rainfall to be significant and for the purposes of our assessment we have considered the rainfall to be consistent throughout the Project area.

We have used the higher of the rainfall values from the Mahurangi rainfall data within our Universal Soil Loss Equation (USLE) sediment yield calculations. The data we used (as detailed within Section 2.3 of WAFR 1) is based on an average of the Mahurangi Upper and Mahurangi Lower rain gauge.

Table 4: Comparison of 100 year ARI 24 hour rainfall depths (mm) along the Project route

2013 (Current Climate)	Pūhoi Rainfall (mm)			Mahurangi Rainfall (mm)		
ARI (year)	TP108	HIRDS V3	Rain Gauge (Orewa)	TP108	HIRDS v3	Rain Gauge (Max of Warkworth and Mahurangi)
100	280	256	157	310	279	237
10	190	153	122	210	169	166
2	115	101	89	130	113	118

3.2 Catchment description and topography

3.2.1 Catchment description

Moving from the south to north, the indicative alignment passes through the Pūhoi River catchment - initially through the tidally influenced areas of the Pūhoi River and then across the Hikauae Creek, before crossing into the Mahurangi Catchment.

The Mahurangi River is the main tributary of the Mahurangi estuary and harbour. The Mahurangi estuary is a long estuary flowing southwards from Warkworth. There are many small bays and estuaries along the sides of the estuary with two larger arms (Pukapuke Inlet and Te Kapa River) to the south. Many of the small bays and upper estuaries are dry during the tidal cycle and are comprised of soft muddy sediments. The remainder of the harbour has large areas of permanent water and harder sediments.

Pūhoi is situated at a low elevation within the Pūhoi River valley, near the estuary and the coast. In general, the topography to the north and west of Pūhoi rises steeply with several prominent landforms located in the area, including Schedewys Hill and Windy Ridge. The terrain continues to rise through to Moirs Hill, which represents the catchment divide between the Pūhoi and Mahurangi Rivers. The Pūhoi estuary is a thin narrow tidal estuary and is much smaller than the Mahurangi.

Table 5 below provides an overview of the catchment description along the Project route from south to north.

Table 5: Overview of catchments along the indicative alignment

Catchment	Landform and land-use
Hikauae Creek – Pūhoi River Catchment	The indicative alignment passes through relatively steep slopes of plantation forestry to the west of the existing State highway. There are a number of small unnamed tributaries through this area. The route then crosses undulating farmed pasture land before crossing the main creek and heading back into areas of steeper slopes and deep incised gullies in forestry land in the headwaters of the creek. Some areas of native vegetation exist alongside watercourses in the forestry areas.
M15 tributary of Mahurangi River (Right Branch)	This unnamed tributary of the Mahurangi River contains steep slopes and many small channels throughout the forestry area. It is almost entirely under plantation forestry. The tributaries flow together and meet the main right branch channel near the existing State highway.
M16 and M19 Tributaries of Mahurangi River (Right Branch)	The indicative alignment passes initially through relatively steep slopes over a number of small tributaries in plantation forestry. The upstream catchment is predominantly in plantation forestry land-use. The alignment then passes into undulating pasture/lifestyle properties with slopes generally becoming shallower as the route heads north.
Mahurangi River (Left Branch)	The indicative alignment passes through generally flatter land near to the main stem of the left branch of the river which is predominantly used for pasture and lifestyle land-uses. The left branch combines with the right branch of the Mahurangi near the junction of Woodcocks and Falls Roads.

Rural production, particularly pastoral farming, forms the predominant land-use, with existing water quality demonstrating the presence of some nutrient inputs and elevated turbidity levels. The Freshwater Ecology Assessment Report outlines the details of the ecological values of these environments.

Table 6 below compares indicative alignment areas with the total catchment. These comparisons illustrate the relatively small percentage of the Project area to the catchment area. Figure 5 also shows the location of the indicative alignment and associated catchment boundaries.

Table 6: Areas affected by the works within catchments

Catchment	Total Catchment Area (ha)	Designation Footprint (ha)	Designation Footprint (% of total catchment area)	Earthworks Footprint (ha)	Earthworks Footprint (% of total catchment area)
Mahurangi River Catchment	5825	369	6.3%	101	1.7%
Pūhoi River Catchment	5252	306	5.8%	77	1.5%

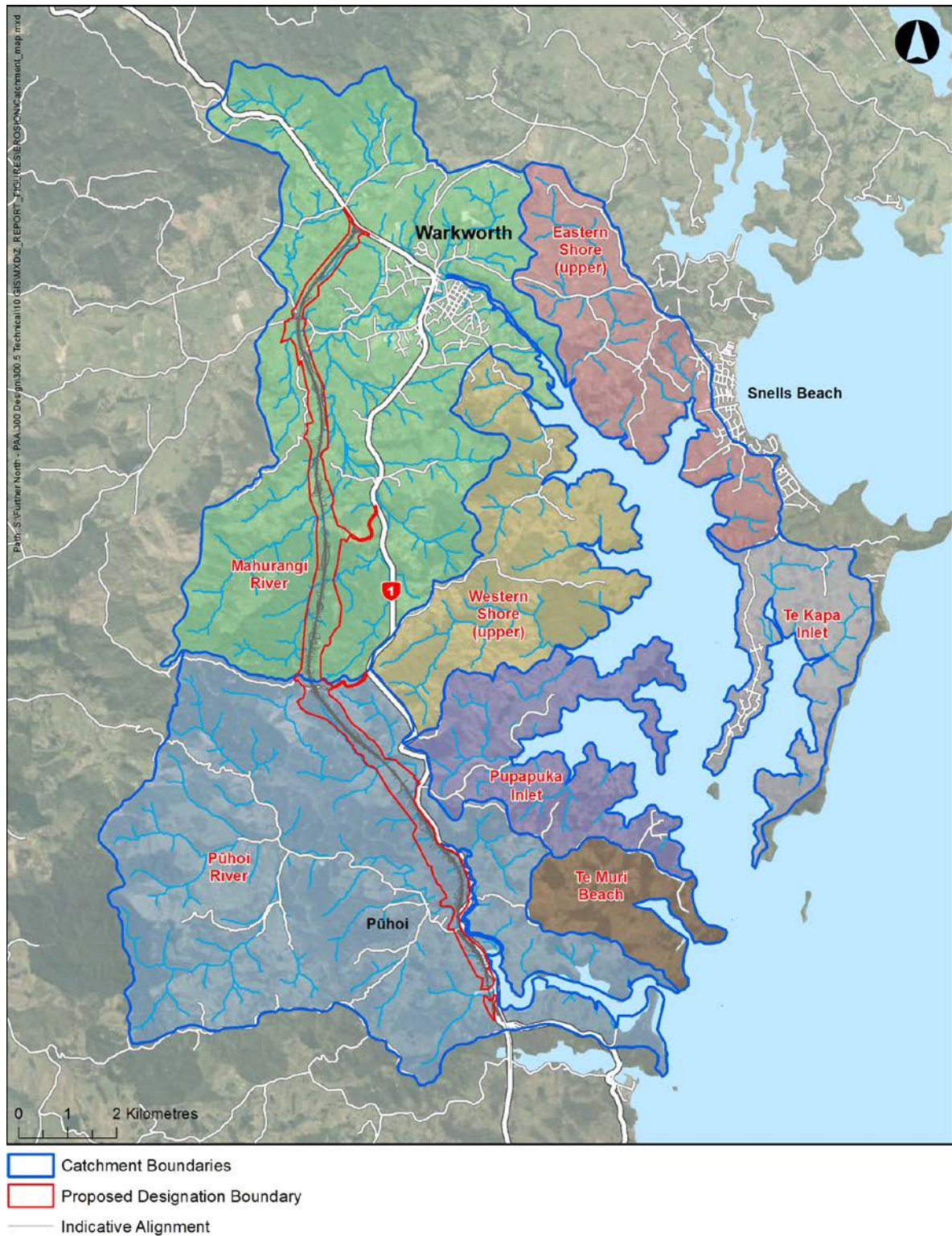


Figure 5: Catchment overview (Further North, 2013)

3.2.2 Topography

With the exception of the main river valleys and the areas associated with the coastline, the Project area is largely characterised by low open undulating hill country in the north, and steeper rolling hill country with interconnected ridge and valley systems in the centre and south. The landscape of the area is characterised predominately by farm land and forestry areas.

The Project topography immediately south of Warkworth is generally flat.

From an ESC perspective, the Project is split into Hill Country and Flat Country as shown in Figure 6. Drawings ES-101 to ES-117 show our analysis of the existing slopes that exist within the Project. This is summarised in Table 7 of this Report.

The results of our analysis show that approximately 45% of the Project's overall earthworks footprint area will be steeper than 15 degrees with approximately 55% of the area being less than 15 degrees. For the purpose of this Report, steeper areas are defined as slopes over 15 degrees. This slope is selected to ensure consistency with the ARP:SC rule framework and also is reflective of a slope angle whereby erosion on slopes above this threshold is more significant. When considered in an ESC context, we consider this topography to be a key feature of the Project.

Table 7: Slope areas within the proposed designation boundary and earthworks footprint (areas based on GIS analysis)¹

Slope classification	Area within designation boundary (ha)	Area within Earthworks Footprint (ha)
0° - 3°	68.9	19.0
3° - 6°	66.7	20.0
6° - 9°	70.7	20.4
9° - 12°	71.9	20.3
12° - 15°	69.0	18.8
15° - 18°	64.9	17.0
18° - 21°	59.7	15.0
21° - 24°	52.7	12.8
24° - 27°	44.9	10.6
27° - 30°	35.0	8.4
>30°	69.4	16.5
Total Area	673.8	178.8

¹ Note: the total earthworks footprint area that was used in our sediment yield models was derived from the Mass Haul analysis, which gave a total area of 188 ha (as opposed to 178.8 ha).

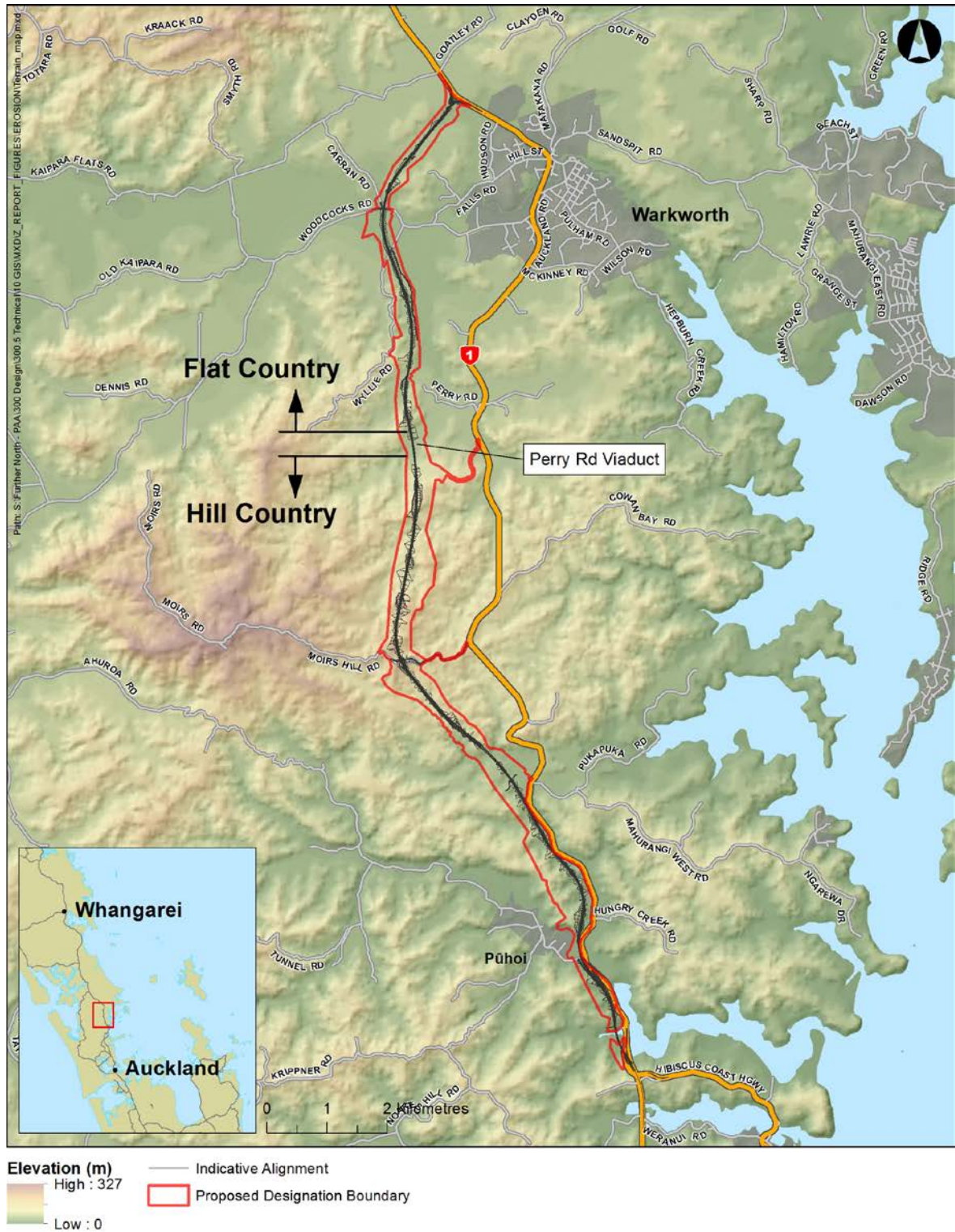


Figure 6: Flat Country and Hill Country location (Further North, 2013)

3.3 Geology²

The majority of the Project area is underlain by rocks of the Waitemata Group – the Pakiri Formation as shown in Figure 7. Also present within the Project area are rocks of the Northern Allochthon (previously known as Onerahi Chaos).

The Tauranga Group is also noted within the Project consisting of alluvium and colluvium with interbedded peat soils in the valley floors.

This geology presents a challenging construction project in terms of stability while also providing an opportunity to work with the more competent Pakiri Formation, which will be earthworked during the winter period.

Geological processes have resulted in a complex arrangement and combination of weak to moderately strong sandstones and mudstones with large lenses of disrupted slices of significantly weaker, highly sheared mudstones, siltstones, sandstones and limestones of the Northern Allochthon. Thrust faults define many of the boundaries between Pakiri Formation and Northern Allochthon sheets.

The steep terrain along much of the Project alignment results in much of the overlying soils being either unstable or highly susceptible to erosion when exposed to certain climatic and ground cover conditions. In addition, on the NGTR (immediately south of the Project), ongoing sediment has been observed to be generated from exposed cut batters post construction, which is evidenced in a number of the operational stormwater ponds and rock lined swales along this section of completed highway. The management of these slopes during construction is discussed within Sections 5 and 6 of this Report with the sediment generation during the operational phase of the Project being discussed in the Operational Water Assessment Report.

² The Geotechnical Engineering Appraisal Report provides a comprehensive description of the Project area geology.



Figure 7: Geologic map for Orewa to Warkworth (Further North, 2013)

3.4 Hydrogeology

The Hydrogeology Assessment Report provides an assessment of the potential effects of the construction and operation of the Project on the existing groundwater regime. The following paragraphs are derived from that report.

The Project area has poorly yielding aquifers with some localised zones of better yielding aquifers associated with faulting and shallow alluvial deposits. Different geologic groups exhibit different groundwater characteristics:

- Northern Allochthon rocks can display highly variable and complex hydrological conditions;
- The Pakiri Formation often contains perched or leaky water tables; and
- Tauranga Group materials found within the river valleys and estuarine embayments have higher yielding aquifers. However, as these are often shallow in nature, they are susceptible to surface contamination.

The base flow of rivers and streams in the Project area is fed from water sources within the geological structure as set out above. The Further North Hydrogeology Team consider that the extended base flow in the waterways will not have an extended recession curve and the smaller streams will tend to dry quicker in comparison to the Waitemata series stratigraphy found to the south of Auckland.

The Freshwater Ecology Assessment Report has confirmed this conclusion during stream surveys for the Project that took place following the extended period of dry weather from December 2013 to April 2013.

3.5 Existing geomorphology and erosion occurring

As detailed above, the geology and topography of the Project area results in some relatively high erosion prone areas, particularly within the Hill Country areas.

We have witnessed evidence of existing erosion in the Project area (i.e. mass movement and soil slip) through a series of site visits. This existing erosion will form part of the sediment yield that currently enters the receiving environments. While this sediment source is not included in our sediment yield calculations it is a source that is likely to continue.

Through the development of Construction Erosion and Sediment Control Plans (CESCPs) for the Project, existing and potential mass movement will be addressed. The Geotechnical Engineering Appraisal Report outlines the general methodology and process to be followed for both existing and potential mass movements. This process is largely based on the geotechnical mapping and understanding of the Project area prior to earthworks commencing.

We also note that previous ARC research of the vegetation removal operations within the Mahurangi catchment highlights the significant mass movement that occurs in these catchments (Auckland Regional Council Mahurangi Modelling Study (Redwoods Site) – Working Reports (1995 and 1997)). While this study does not show a direct linkage between the sediment generation and yield and the vegetation removal operations that were occurring within the forested catchments of

Mahurangi, there is a direct linkage with large sediment yields resulting over the earthworks phase of the forestry harvesting activities.

3.6 Water quality

Water quality in the Project catchments has been characterised based on literature, existing data and by monitoring, and is summarised below. The water quality monitoring results have been assessed in the Freshwater Ecology Assessment Report, and are summarised in WAFR 4.

Within the context of water quality, where reference is made to guidelines, these refer to the following:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1, The Guidelines. Australia and New Zealand Environment and Conservation Council (ANZECC), 2000;
- Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment (MfE), 2003;
- Resource Management (National Environmental Standards for Sources of Human Drinking Water) Regulations, 2007; and
- Drinking-Water Standards for New Zealand 2005 (Revised 2008). Wellington: Ministry of Health, 2008.

3.6.1 Literature and existing data review

A review of existing literature relevant to the Project area, including documents associated with the Mahurangi Action Plan (2010), indicates that sedimentation is one of the key issues within the Mahurangi Estuary. The Mahurangi River is a contributor to the sediment deposition within the Mahurangi Harbour, as are all the other catchments around the estuary. Auckland Council has been undertaking monitoring for approximately 20 years at three locations in the Mahurangi River catchment (identified in Figure 8 below). The general conclusions about the water quality of the Mahurangi River Catchment that can be drawn from analysis of this data are as follows:

- Monitoring site AC-FHQ is located in the upper catchment at the Forestry Headquarters on the lower end of the M16 tributary of the Mahurangi. At this location the median water quality results are generally within relevant guidelines indicating good water quality, with turbidity being slightly above guideline values. Nitrogen concentrations are generally within guidelines whereas phosphorus is at the guideline values, with phosphorus concentrations decreasing over time. Auckland Council rated this site as having excellent water quality when compared to other water quality monitoring sites in the Auckland region;
- Monitoring sites AC-WTP and AC-TB are located at Warkworth. These sites indicate good water quality. Turbidity was slightly elevated, as is phosphorus. Concentrations of phosphorus and nitrogen at these lowland sites are higher than the upper catchment, which is likely to reflect agricultural land-uses within the lower catchment;
- The median concentrations of trace metals are below guidelines at both of the lowland sites. However the trace metal concentrations are higher at the downstream location, again being indicative of land-use impacts;

- Overall when considering the mean and median water quality data for the Mahurangi River, the water quality is suitable for supporting aquatic ecology and also suitable for stock watering, irrigation and fish farming uses; and
- Microbiological data indicates some contamination of the Mahurangi River with mean results being slightly above alert levels, but medians are below guidelines at AC-WTP and AC-TB.

Auckland Council has also gathered data from two sites in the Mahurangi Estuary for approximately 20 years. This Mahurangi Estuary saline water monitoring indicates that the estuary has good water quality with most parameters being below guidelines. Total Suspended Solid concentrations were above guidelines at the Dawson's Creek site (located in the Upper Mahurangi Harbour) higher up the estuary, but within guidelines at the Mahurangi Heads and appear to be declining over time. Median total phosphorus concentrations were elevated above guidelines at both sites. Auckland Council rated the estuary as having excellent water quality.

There is no publicly available literature or historical water quality data for the Pūhoi River catchment. We have undertaken some sampling and draw conclusions from these about water quality in this catchment as discussed below.

3.6.2 Monitoring of existing environments

Monitoring has been undertaken to characterise the water quality of the streams within the Project area. Water quality data was gathered for the Project from thirteen sites across the Project area as shown in Figure 8 (including all Further North Monitoring Sites and two Auckland Council Monitoring Sites – AC-WTP and AC-FHQ). Two of these sites were at the mouths of the two streams in brackish waters and the other eleven were freshwater sites. We chose these eleven freshwater sites to be representative of the land-uses and activities in the Project area. Sampling covered both low and higher flow conditions. Four sets of samples were taken at each of the eleven sites in April and May 2013.

This data has been compared to water quality guidelines and the existing Auckland Council data discussed above. We then made an overall summary of the character of the water quality. This data is intended to provide a characterisation and we recognised that it covers a small timespan only and is not a detailed baseline of all water quality conditions over the full calendar year.

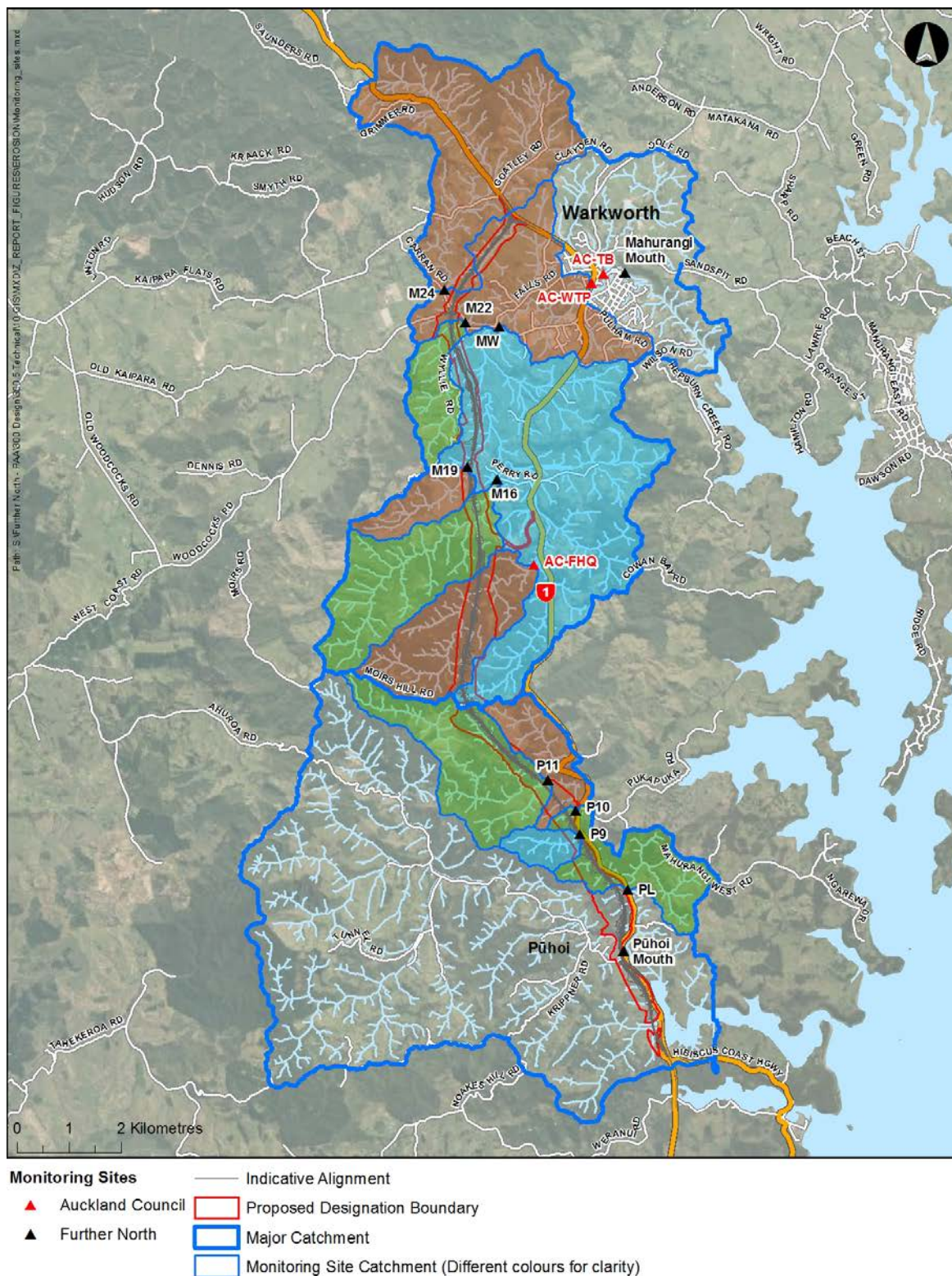


Figure 8: Water quality monitoring locations (Further North, 2013)

3.6.3 Water quality results

Water quality results are discussed separately for dry and wet weather sampling conditions and for the sediments further details are provided in WAFR 4.

(a) Dry weather sampling

We gathered two sets of dry weather data at the eleven freshwater sites during the autumn of 2013. Stream velocities were very low on the first sampling occasion with no measurable flow existing at some sites. The majority of the results were below ANZECC default trigger values for aquatic ecosystems. Hydrocarbon concentrations were all below detection limits. Metal concentrations and *Ecoli* counts were all below guideline values.

Occasional exceedances of guidelines occurred for turbidity, ammoniacal nitrogen and dissolved and total reactive phosphorus. The exceedances occurred at sites P9 and P10 in the middle of the Hikuaea Creek and M24, AC-WTP and AC-FHQ at on the Mahurangi River.

The parameters that were in exceedance of guidelines are comparable to the available long-term Auckland Council data, which showed a similar pattern of exceedance in average results.

Clarity was the only parameter that frequently exceeded guideline values with 13 of 22 samples having low clarity and reflects the general exceedance of clarity guidelines in Auckland Council data along with observations of the Project team that identified generally low clarity waters in low flow conditions.

Based on our dry weather sampling we consider the Project data to be broadly similar to the Auckland Council water quality data. There are no obvious differences between the data from the two catchments or specific sites in different land-uses/stream network elevations.

(b) Wet weather sampling

We gathered two sets of wet weather data at the eleven freshwater sites during the monitoring period in autumn 2013. The main notable difference to dry weather results was that turbidity was elevated at all sites except the small stream M22 in the Mahurangi River, and clarity was generally below guidelines. Metal concentrations were all below guideline values and therefore from this data it would appear that metal concentrations are low in both catchments in both wet and dry weather conditions. Some exceedances of total, ammoniacal or nitrite/nitrate nitrogen occurred during one round of the wet weather samples. Phosphorus concentrations were elevated in one third of the samples in the same sample round.

These exceedances occurred at various sites in both catchments. The first (8th May) wet weather sampling round had a greater number of exceedances of guidelines than any other sampling round. During the second wet weather event nitrogen and phosphorus guidelines were generally not exceeded.

Overall a similar pattern of exceedance of guidelines occurred in wet weather as in dry weather conditions with no hydrocarbons, low concentrations of metals and occasionally elevated nutrient concentrations (both nitrogen and phosphorus). Total nitrogen was notably only exceeded during

wet weather conditions. Clarity was almost always low in both flow conditions and turbidity was higher in wet weather conditions as would be expected.

We gathered additional data from the mouths of the Pūhoi and Mahurangi Rivers in wet weather conditions in March 2013. These locations are brackish estuarine waters. We took four samples were taken at each site over a 4 hour period. Exceedances of guideline values were observed for a number of parameters as follows:

- Total and dissolved copper from all samples at the Mahurangi Mouth;
- Dissolved and total zinc from one sample at the Mahurangi Mouth;
- Total nitrogen, total ammoniacal nitrogen and nitrate/nitrite nitrogen in all samples; and
- Total and dissolved phosphorus in all samples from the Mahurangi Mouth and most from the Pūhoi.

A review of the data indicates that nutrients are generally elevated at the stream mouths in wet weather. Bacteria concentrations indicate the water may be unsuitable for contact recreation. The metal results indicate a difference between the two catchments with the Mahurangi River having higher results of Copper and Zinc. This difference may be a reflection of the inputs from the urban areas of Warkworth that are not identified in the monitoring at the other locations.

(c) Sediment quality results

Sediment quality is good with all contaminant contributions being below guidelines at all sites sampled in both the Mahurangi and Pūhoi Rivers. Estuarine sediment quality assessed in the Marine Ecology Assessment Report identifies that marine sediment quality is also very good in the Pūhoi and the lower Mahurangi Estuary. Copper is elevated in the upper Mahurangi Estuary, with Copper detected in the 63µm fraction in the amber Environmental Response Criteria (ERC) range at Vialls Landing and Jamiesons Bay, and above both the ERC red and Interim Sediment Quality Guidelines (ISQG) - low thresholds in total sediment at Vialls Landing.

3.6.4 Summary of water quality

Overall existing Auckland Council data and the Project monitoring data identify that water quality is reasonably good across the freshwater catchments. Data gathered for the Project presents a similar picture of water quality to that provided by Auckland Council data and does not indicate significant differences between the Mahurangi and Pūhoi catchments. Suspended solids and turbidity are generally elevated resulting in low clarity. Metals are generally in low concentrations and hydrocarbon concentrations are very low. Nutrients (nitrogen and phosphorus) are occasionally elevated above guidelines.

Sediment quality is good in both the fresh water and marine environments of the Mahurangi and Pūhoi catchments. Saline water quality is good in the Mahurangi Estuary with slight elevations of TSS and nutrients. No water quality data is available for the Pūhoi Estuary, however we anticipate that it also has good water quality because the freshwater monitoring indicates that both catchments' water quality are similar and the sediment quality is also currently similar.

Based on the average water quality data, we consider the Mahurangi River to be suitable for preservation of aquatic ecology values and suitable for stock watering, irrigation and fish farming uses.

3.7 Overall sensitivity of the receiving environment

Based on our consideration of the existing environment, from a construction water management perspective, we consider the potential environmental issues for the Project to be as follows:

- **Changes in hydrology** - These changes are discussed in the Operational Water Assessment Report, including changes to catchment runoff and stream flow, changes to flood risk and changes to stream channel and stream bed morphology;
- **Changes to water quality** – Assessments of impacts on water quality have been undertaken as discussed in the Freshwater Ecology and Marine Ecology Assessment Reports, which identify changes in water quality that may occur as a result of the Project construction, such as the discharge of sediment from earthworks, discharge of other contaminants and the discharge of sediment from stream activities; and
- **Changes to ecology and habitat** - These changes have been assessed in the Freshwater and Marine Ecology Assessment Reports. Key potential effects arise from changes to flora and fauna and changes to habitat.

3.8 Magnitude of effects

Within this Report we assess the magnitude of ecological impacts using the same criteria as defined within the Marine Ecology Assessment Report and adapted as below.

Table 8: Criteria for describing impact magnitude

Magnitude		Description
Significant	Very High	Total loss or very major alteration to key elements/features of the baseline conditions such that the post development character/composition/attributes will be fundamentally changed and may be lost from the site altogether.
	High	Major loss or major alteration to key elements/features of the baseline (pre-development) conditions such that post development character/composition/ attributes will be fundamentally changed.
Moderate		Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/composition/attributes of baseline will be partially changed.
Minor		Minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible but underlying character/composition/attributes of baseline condition will be similar to pre-development circumstances/patterns.
Negligible		Very slight change from baseline condition. Change barely distinguishable, approximating to the 'no change' situation.

4. Overview of erosion and sediment control

Fundamental erosion and sediment generation principles are as follows:

- Sediment Generation is defined as that which is generated on the site;
- Sediment Delivery is the amount of eroded sediment that is not retained onsite in depressions and within the natural contours prior to it entering any sediment treatment devices;
- Sediment Yield is that sediment which enters the receiving environment; and
- Sediment Load is the mass of sediment carried in suspension within rivers and marine waters.

The ESC approach for the project is based on the minimisation of sediment generation and the retention of sediment such that sediment yields are also minimised.

Erosion control measures (designed to minimise the generation of sediment in the first instance) that could be used on the Project include:

- Construction staging and sequencing;
- Diversion channels;
- Contour drains;
- Stabilisation;
- Stabilised construction entrances; and
- Flumes and Pipe drop structures.

Sediment control measures (designed to capture any sediment that is generated during construction) that could be used on the Project include:

- Sediment retention ponds;
- Decanting earth bunds;
- Super silt fences;
- Container impoundment systems; and
- Chemical treatment.

ESCs are either structural controls (physical measures) or non-structural controls (management practices) such as methodologies and works sequencing and staging.

The design of the structural controls considered in this report is based on Auckland Regional Council's 'Technical Publication 90 – Erosion and Sediment Control: Guidelines for Land Disturbing Activities in the Auckland Region' (TP90) with additional innovative measures and practices on noted in some areas of the Project.

4.1 Erosion and sedimentation process

Erosion occurs when the surface of the land is worn away (eroded) by the action of water, wind, ice or geological processes. Through the erosion process, soil particles are dislodged, generally by rainfall and surface water flow. As rain falls, water droplets concentrate and form small flows. As this flow moves down a slope, the combined energy of the rain droplets and the concentration of flows has the potential to dislodge soil particles from the surface of the land.

Sedimentation occurs when these soil particles are deposited. The amount of sediment generated depends on the erodibility of the soil, the energy created by the intensity of the rain event, the site conditions (for example the slope and the slope length) and the area of bare earth or unstabilised ground open to rainfall.

The following terms represent the key aspects of ESC:

- **Sediment generation** – this highlights the generation potential of the area in question and is based on slope, slope length, soils, rainfall and erosion control factors.
- **Sediment delivery** – this relates to the amount of eroded material that is not retained onsite in depressions and within the site's natural contours prior to it entering any sediment treatment devices.
- **Sediment yield** – the amount of sediment that actually leaves the site and enters the receiving environment.
- **Sediment load** – the mass of sediment carried in suspension within rivers and marine waters.

Erosion control is based on the practical prevention of sediment generation in the first instance. If erosion control measures and practices are effective then sediment generation will be minimised and the primary reliance on the sediment control measures is reduced.

Sediment control refers to management of the sediment after it has been generated. It is inevitable that some sediment will be generated through land disturbance activities even with best practice erosion control measures in place. Sediment control measures are designed to capture this sediment to minimise any resultant sediment-laden discharges to waterways.

Rather than primarily relying on sediment control measures, reducing erosion will have the direct effect of reducing sediment generation and therefore less sediment laden runoff will need to be intercepted, treated and discharged from the sediment control measures.

In addition to ESC structural practices, which include physical measures such as sediment retention ponds, the Project will use a series of non-structural practices that will focus on various site management practices, such as staging and sequencing of construction works, and providing an appropriate level of resourcing for environmental management and monitoring. Section 8 of this Report outlines the proposed monitoring programme for the Project.

With the above in mind, the ESC measures for the Project are designed to minimise the extent of soil erosion and manage any resultant sediment yield. Erosion control will be the highest priority in the design of Project ESC measures as it prevents sediment generation in the first instance.

We also consider non-structural measures to be crucial in avoiding significant environmental effects. Examples of structural and non-structural measures include:

- **Structural**

- ESC device installation;
- SRP Baffles;
- SRP decant pulleys; and
- Rainfall activated chemical treatment devices.

- **Non-Structural**

- Manual batch dosing of Sediment Retention Ponds (SRPs) and Decanting Earth Bunds (DEBs) with chemical flocculants during pumping operations;
- Significant pre, during and post rain inspections;
- Implementation of an adaptive monitoring programme; and
- Selection of all discharge locations (and the timing) to the receiving environment to ensure sensitive areas and times are avoided.

4.2 Erosion and sediment control guidelines

We have assessed the NZTA draft standard and have determined that TP90 represents best practice and will achieve the necessary environmental outcomes for this Project. This is not to say that we have disregarded the draft standard, and in some circumstances we consider the draft standard being appropriate for use on the Project (e.g. Sections 5 and 6 of this Report). We have also incorporated the general principles from both TP90 and the draft standard within the construction water management approach as outlined within this Report.

4.3 Erosion and sediment control development process

Our assessment of the ESC measures and management practices likely to be required along the length of the Project is based on the conceptual construction sequencing discussed in Section 6 of the AEE.

Further discussion and approval of the ESC measures approved as part of the consenting process may be required prior to construction, this will take place where necessary through the preparation of site and activity specific CESCPs (Construction Erosion and Sediment Control Plans).

CESCPs are detailed erosion and sediment control plans which will be submitted for specific work areas or activities within the site. They will provide the detailed design, specific ESC measure location, staging and sequencing of works for that location. The CESCPS will be developed prior to works commencing in these locations. The CESCPS will determine specific measures to be employed and in this regard will consider the alternatives that exist.

The CESCPS will take into account the various environmental and ecological values and will then determine the most effective and appropriate form of ESC devices and management practices

required to manage erosion and sedimentation on a site-by-site basis, during the construction period. The process of CESC development is illustrated in Figure 9 below.

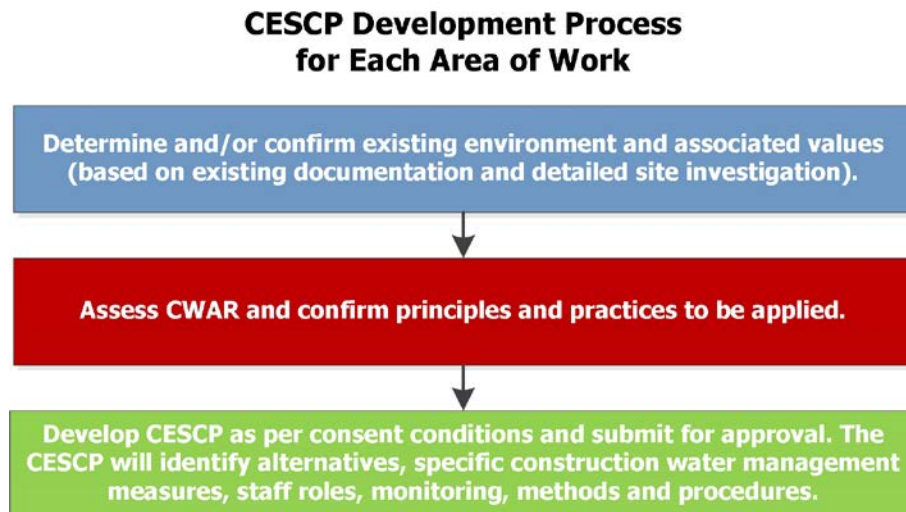


Figure 9: The CESC Development Process (Further North, 2013)

Below is a summary of the ESC devices and management practices that will be adopted during the construction phase of the Project.

4.4 Key erosion control measures

In general, the erosion control measures to be applied to the Project are as follows:

4.4.1 Construction staging and sequencing

The extent of exposed soil and length of time that area is exposed has a direct influence on the sediment yield leaving a particular area of the site. Bulk earthworks and construction activities will be staged and sequenced in order to limit the area of exposed soil required to complete an element of the work. Open earthworks areas will be progressively stabilised to reduce the potential for erosion to occur.

4.4.2 Clean and dirty water diversions (CWD and DWD)

CWDs provide for the controlled conveyance of stormwater runoff and will be used on the Project to prevent run on water from the undisturbed catchment above the works from entering the construction area.

CWDs will be designed to cater for the 20 year ARI rain event. This design is consistent with TP90 and will ensure that the works are sufficiently protected from flows from the natural catchment outside of the works.

We note that the NZTA sizing is based on the 100 year ARI rain event with 1 hour duration. The NZTA calculations result in smaller peak flows and therefore we remain confident that TP90 is the most applicable standard.

DWDs transfer sediment laden water to sediment retention devices for treatment. They are effectively a conveyance device and, as with the CWDs, are designed to cater for the 20 year ARI rain event. The DWD design criteria for the Project will ensure that all construction runoff from rain events up to the 20 year ARI event will be transferred to treatment devices in accordance with TP90.

CWDs will be fully stabilised with either vegetation or geotextile cloth. DWDs will be stabilised dependent upon soil type for the specific area of works. The NZTA guideline provides an appropriate standard with clay soils having a 1.14 m/s limitation and silt based soil a 0.61 m/s limitation for maximum velocities. If, through the development of CESCPS, velocities are calculated that exceed these limits, then stabilisation will be required.

A maintenance programme will be implemented during Project construction activity to remove the resulting sediment deposited within the channels. During construction, excavated pits or sumps will also be positioned along the channels to retain sediment yield.

Table 9 and Table 10 below provide a range of sizes and dimensions of CWD and DWD channels and bunds to be used on the Project. Details of the design calculations are included in WAFR 1. Drawing ES-152 illustrates the CWD and DWD.

Table 9: Examples of CWD design

Catchment Areas (ha)	TP108: 20 year ARI Peak Flows (m ³ /s)	Channel depth (m)		Bund height (m)	
		at 2% slope	at 5% slope	at 2% slope	at 5% slope
0.50	0.161	0.32	0.27	0.62	0.57
1.00	0.322	0.42	0.35	0.72	0.65
2.00	0.644	0.55	0.46	0.85	0.76
3.00	0.966	0.63	0.53	0.93	0.83
5.00	1.610	0.77	0.65	1.07	0.95
10.00	3.220	1.00	0.84	1.30	1.14

Table 10: Examples of DWD Design

Catchment Areas (ha)	TP108: 20 year ARI Peak Flows (m ³ /s)	Channel depth (m)		Bund height (m)	
		at 2% slope	at 5% slope	at 2% slope	at 5% slope
0.50	0.1931	0.17	0.14	0.47	0.44
1.00	0.3862	0.22	0.18	0.52	0.48
2.00	0.7724	0.28	0.24	0.58	0.54
3.00	1.1587	0.33	0.28	0.63	0.58
5.00	1.9311	0.40	0.34	0.70	0.64
10.00	3.8622	0.52	0.44	0.82	0.74

4.4.3 Contour drains

Contour drains are temporary ridges or excavated channels or a combination of the two that are constructed to convey water across a slope at a minimum gradient. They reduce the slope length and therefore the velocity of water flowing down disturbed slopes and hence reduce the erosive power of construction runoff.

4.4.4 Rock check dams

Check dams are small dams made of rock or other non-erodible material constructed across a swale or channel to act as a control structure. The purpose of a check dam is to reduce the velocity of flow within the channel and prevent scour of the channel surface. Check dams also allow for some settlement of suspended solids within the channel.

4.4.5 Stabilisation for erosion and dust management purposes

Stabilisation is a key element of the Project and will include mulching, geotextile and the use of hard fill material.

Progressive and rapid stabilisation of disturbed areas will be ongoing throughout the Project. Mulch will include hay/straw and wood bark generated onsite through the removal and mulching of existing vegetation as appropriate. Stabilisation will particularly apply at stockpile areas and batter establishment to reduce both erosion and dust generation.

Mulching will typically apply to slopes of less than 15 degrees, above which alternatives such as geotextile will need to be considered. The development of the CESCOs will determine the specifics of this stabilisation technique and timing.

Stabilisation will be undertaken with three key purposes:

- To achieve the open area limitations as specified within consent conditions for the Project;
- To reduce the open area of higher risk locations to assist with a reduction in sediment generation; and
- In response to the adaptive monitoring programme to address any potential effects or undesirable monitoring trends.

4.4.6 Pipe drop structure / flume

Temporary pipe drop structures or flumes are constructed to convey construction runoff down a slope face without causing erosion of the slope and will be used to ensure no scour of these batters occurs. These structures will be designed and implemented as per Drawing ES-153.

4.4.7 Stabilised construction entrance way

Stabilised Construction Entrance Ways are a stabilised pad of aggregate placed on a filter base and are located where construction traffic will exit or enter a construction site. They help to prevent site entry and exit points from becoming a source of sediment and also help to reduce dust generation and disturbance along public roads.

No vehicles will be allowed to leave the Project site unless tyres are clean and vehicles will not contribute to sediment deposition on public road surfaces.

4.5 Key sediment control measures

Sediment control on the Project will involve the interception and treatment of sediment-laden runoff from the various construction areas along the Project and will be carried out in accordance with the guidelines contained in TP90. Sediment control will be established through the use of recognised sediment control measures and site management practices.

Sediment control devices will be located outside the 20 year ARI flood level, unless no other viable alternative exists. If sediment control devices are required within the 20 year ARI flood level, they will be designed to capture the minimum catchment area and will be subject to an increased inspection and maintenance regime.

The general sediment control measures and principles to be used on the Project are as follows:

4.5.1 Sediment retention pond (SRP)

Treatment of construction runoff will be carried out to ensure that sediment is removed to the maximum extent possible from the construction runoff before being discharged to the receiving environment.

SRPs will be designed to receive the flows from the upstream catchment during a 100 year ARI rain event.

SRPs will be designed with a minimum 3% volume criterion applied in relationship to catchment size (i.e. 300m³ SRP volume per 10000 m² or 1ha of contributing catchment). This criterion is consistent with TP90. SRP spillways will be designed and constructed to ensure that they safely pass the 100 year ARI rain event with low velocity, which will reduce the risk of scour on the downstream side of the spillway.

Forebays of SRPs will be established that are designed to capture the majority of the sediment entering the SRP. Any sediment that is not captured within the forebay area will be transferred into the main body of the SRP and will be captured through the provision of baffles within the SRP itself.

We note that as part of the SRP construction, it will be necessary to do the following:

- Check ground conditions through the use of bore holes to undertake a geotechnical assessment of the proposed SRP site;
- Determine the need or otherwise for a shear key establishment; and
- Remove any unsuitable material and confirm ground conditions as appropriate for SRP establishment.

This specific detail will be provided within a CЕСP.

Table 11 (below) shows the design dimensions for a sample reference of SRPs based on the conceptual ESCPs for the Focus Areas.

Table 11: Sample of sediment retention pond sizes based on conceptual Focus Area ESC

Pond/Catchment Properties		Pond Storage Volumes (m ³)		Pond Top Dimensions (m) at 2m depth	
Discharge Point location (chainage)	Maximum Catchment Area (ha)	Min Total Storage	Forebay Volume	Length	Width
54800	0.69	207	21	26.9	11.9
54600	1.08	324	32	31.3	13.3
52400	1.55	465	47	35.7	14.8
51700	1.90	570	57	38.5	15.7
56100	2.09	627	63	39.9	16.2
50800	2.64	792	79	43.7	17.5
49600	3.86	1158	116	50.9	19.9
54950	4.83	1449	145	55.9	21.5

4.5.2 Decanting earth bund (DEB)

Decanting earth bunds (DEB) are temporary berms or ridges of compacted soil, which are constructed to create impoundment areas where ponding of sediment-laden runoff can occur and which provide time for suspended solids to settle out before the runoff is discharged to the receiving environment.

DEBs will be designed based on a volume of 2% of the contributing catchment area with an ideal length to width ratio of 3:1, but not exceeding 5:1. All spillways from the DEBs will be constructed to safely pass the 100 year ARI rain event with low velocity and therefore minimal scour potential. This criterion is consistent with TP90. Drawing ES-152 illustrates the DEB.

4.5.3 Pumping activities

All SRPs and DEBs will be fitted with floating decants with a mechanism to control outflow such as a manual decant pulley system to be used during pumping activities to these structures. Wherever possible, gravity flow will be used rather than pumping. Where decants are manually plugged, they will only be lowered once an acceptable standard of discharge quality can be achieved. The pumping rates and volumes to SRPs and DEBs will be designed for the total pump volume to be fully captured within the retention structure.

Further pumping will also be required with associated activities such as bridge construction. Pumping flows to SRPs and DEBs ensures that any sediment laden flows are discharged to a treatment device prior to entering the receiving environment.

4.5.4 Container impoundment systems (CIS)

In locations where SRPs or DEBs cannot be located due to slope, room constraints or instability issues, container impoundment systems will be used. These are retrofitted with a decant system and will also be subject to chemical flocculation. We expect these systems will be used primarily in the early stages of earthworks for small catchment areas prior to the ability to develop SRP structures. Drawing ES-155 illustrates the CIS.

4.5.5 Super silt fence (SSF)

Super silt fences are fabric fences reinforced with stakes and a chain-link backing to allow a physical barrier to sediment laden flows leaving the area of earthworks. This barrier acts as a detention and filter for these flows to ensure sediment yield is minimised. Their design and placement will be based upon the criteria contained within TP90. SSFs will be used in those areas of work adjacent to, or in the immediate vicinity of watercourses.

As a risk management tool for SSFs, the fabric will be installed with a minimum 200mm of fabric placed upslope at the base of the trench.

4.5.6 Flocculation

Flocculation is a chemical treatment method for increasing the retention of suspended solids from construction earthworks runoff in SRPs and DEBs. Flocculant is added to the construction runoff flowing into a SRP or DEB via a rainfall activated system (flocculant shed) or via manual batch dosing.

The use of flocculation chemicals increases the efficiency of SRPs and DEBs and reduces the amount of sediment discharged to the receiving environment (sediment yield).

All Project SRPs and DEBs will be chemically treated with a flocculant appropriate for the soil type and discharge location. Based on research undertaken (refer to WAFR 2) it has been demonstrated that chemically treating sediment laden water helps to achieve good water quality.

4.6 Other measures

4.6.1 Permanent stormwater devices

The Project will also include the installation of a number of permanent stormwater treatment wetlands for permanent stormwater treatment from impervious surfaces. Where practical, permanent stormwater treatment and detention devices should be installed early in the Project. Where the location of a SRP coincides with a permanent stormwater treatment wetland, the wetland will be used on a temporary basis as a SRP. These ponds will be converted to long term stormwater wetland features at the completion of the earthworks activity within that sub-catchment.

No existing natural wetlands will be used for primary treatment of sediment-laden runoff from the construction phase.

4.6.2 Decommissioning of devices

All ESC measures will remain in place until such a time as the catchment contributing to that device is stabilised. Once the contributing catchment is considered stabilised the ESC measure will be decommissioned. The decision process and procedure for this will be outlined within the CESCOs.

4.7 Construction water management concepts

Figure 10 below shows the construction water management concepts that are addressed within this Report.

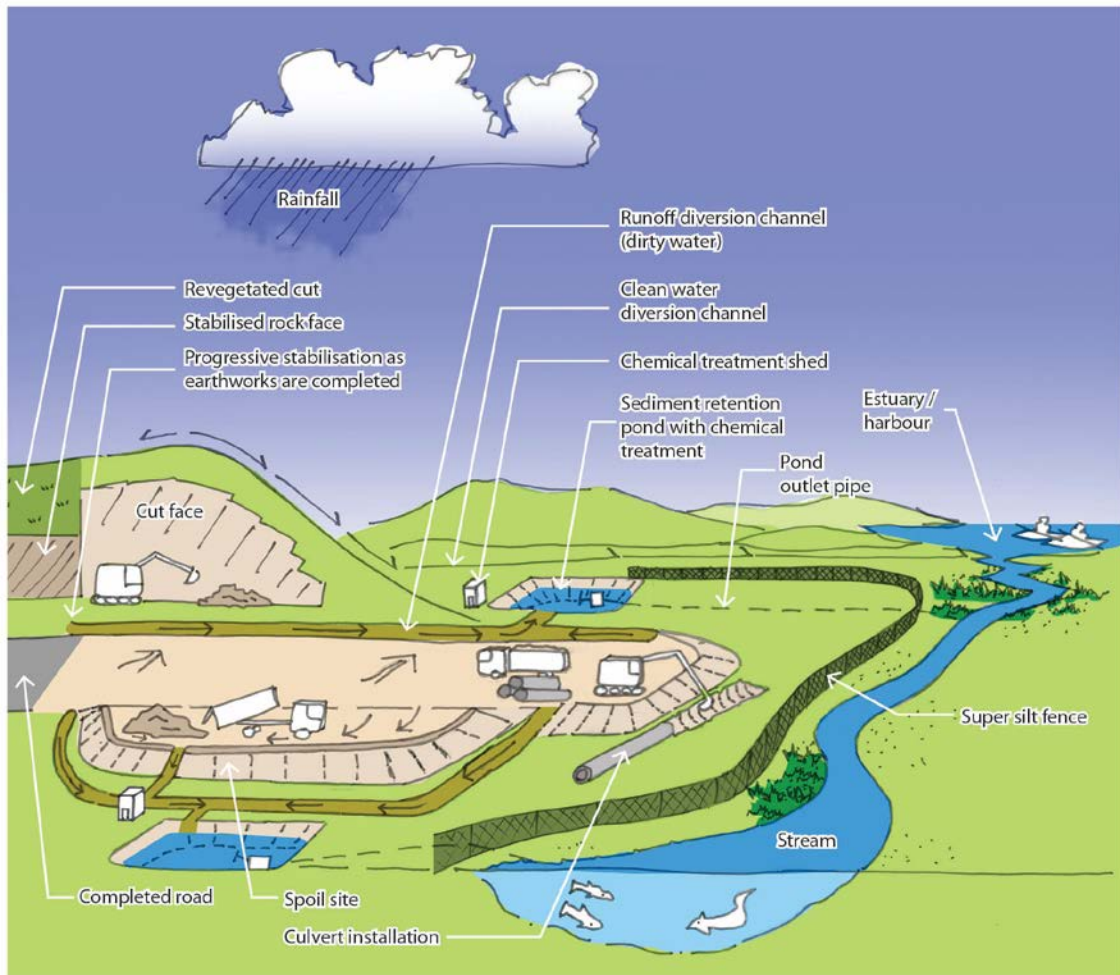


Figure 10: Construction water diagram

4.8 Non-sediment contaminants

Non-sediment contaminants generally consist of site and materials management measures that may directly or indirectly discharge into the receiving environment from site activity.

Potential non-sediment contaminants used in construction activity on the Project are listed in the table below:

Table 12: Potential non-sediment contaminants

Product / work activity	Potential contaminants	Indicator	Non-visible potential contaminants
Adhesives	<ul style="list-style-type: none"> Adhesives Glues Resins Epoxy PVC Cement 	Oily sheen or discoloration from some products	<ul style="list-style-type: none"> Phenols Formaldehydes Asbestos Benzene and Naphthalene
Asphalt Paving	Hot and Cold Mix Asphalt	Oil Sheen	Oil, petroleum distillates, Poly aromatic hydrocarbons
Cleaning Products	Cleaners, ammonia, lye, caustic sodas, bleaching agents, chromate salts	Discolouration	Acidity / alkalinity
Concrete	Cement	Discolouration	Alkalinity (High pH)
Flocculants	Specific to Flocculant used but can include pH and aluminium	Clarity	<ul style="list-style-type: none"> Aluminium toxicity pH
Sanitary Waste	Portable Toilets, disturbance of sewer lines	Discolouration, sanitary waste	Bacteria, Biological Oxygen Demand, Pathogens
Vehicle and Equipment Use	Equipment operation, maintenance, washing, refuelling	Oil sheen, sediment	Total Petroleum, hydrocarbons, coolants, benzene and derivatives

The management of these non-sediment contaminants will be subject to specific best management practice and industry guidelines. It is currently unclear as to the specific nature of these non-sediment contaminants and the associated volumes; however, Table 13 below provides some generic guidance as to the expected management approach for the Project.

Table 13: Potential non-sediment contaminants – management approach

Product / work activity	Management approach
Adhesives	<ul style="list-style-type: none"> • Store materials in an area that is not subject to rainfall contact • Use adhesives carefully and clean up any spilled material • Properly dispose of containers once they are empty
Asphalt paving	<ul style="list-style-type: none"> • Water runoff should discharge to a treatment system designed to capture hydrocarbons
Cleaning products	<ul style="list-style-type: none"> • Store materials in an area that is not subject to rainfall contact • Use adhesives carefully and clean up any spilled material • Properly dispose of containers once they are empty
Concrete	<p>Refer to Section 6.1.7(b) of this Report.</p> <ul style="list-style-type: none"> • Concrete truck chutes, pumps and internals should only be washed out into the formed areas awaiting installation of concrete • Unused concrete remaining in trucks shall be returned to the concrete batching plant • Hand tools should only be washed out into the formed areas awaiting installation of concrete
Flocculants	<p>Refer to Section 6.1.8 of this Report.</p> <ul style="list-style-type: none"> • Ensure the use of flocculants follows an approved flocculant management plan and industry best practice. • Regularly measure pH of the discharge from sediment retention devices.
Sanitary waste	<ul style="list-style-type: none"> • Avoid knocking over portable toilets • Place portable toilets away from site vehicle movement areas • Service portable toilets regularly • Empty portable toilets before they are moved. • Avoid breaking sanitary sewer lines that may exist onsite
Vehicle and equipment use	<ul style="list-style-type: none"> • Fuel storage tanks shall be banded to store a minimum of 100% of the tank's capacity. Note that for this project no bulk fuel storage is expected and mobile refuelling will occur. • Procedures and practices shall be put in place to minimise or eliminate the discharge of lubricants, coolants or hydraulic fluids to the receiving environment • Have spill prevention and control measures and procedures in place

5. Erosion and sediment control – design philosophy and principles for the Project

ESC design criteria and principles will be adopted on the Project. These criteria and principles set the minimum standard for construction water management and will be confirmed through the development of Construction Erosion and Sediment Control Plans (CESCPs).

Certain construction activities are considered to present a high risk of the discharge of sediment to the receiving environment. General principles and management techniques are required to manage high risk activities and summarises the design criteria for a range of ESC measures.

Innovation is considered key in ensuring that erosion and sediment control measures succeed and are effective throughout the Project. Drawing on the experience from other projects we introduce innovative practices that will be implemented on this Project.

5.1 ESC on the Project

This section outlines the general principles for ESC on the Project and sets the context for our assessment. The receiving environment associated with the Project area includes a range of both fresh water and coastal ecological and amenity values. These values are highlighted within the Freshwater and Marine Ecology Assessment Reports.

It is essential that ESC measures and practices implemented during the construction phase of the Project recognise these values and manage the discharge of sediment accordingly. Higher risk areas are identified as those locations within, adjacent to, or connected to, freshwater and coastal environments (due to the immediate vicinity of the works) in addition to those areas of steeper contour as shown in Drawings ES-101 to ES-117 (due to the direct relationship between slope angle and erosion). Refer to Section 5.2 of this Report.

As defined within Section 3 of this Report, steeper areas are defined as slopes over 15 degrees.

The proposed sediment detention device discharge locations are discussed in Section 1.9 of this Report and are indicated in Drawings ES-001 to ES-025. Potential effects of these discharges on the higher risk areas of the Project will be managed through the implementation of appropriate ESC measures over and above those typically implemented within earthworks projects in the Auckland region. Examples of these are provided within Section 4 of this Report.

For the Project, sediment generation will arise from the bulk earthworks phase of the construction operation. Soil types, slopes and the construction methodology are all considered significant influences on this sediment generation.

It is our experience that the NZTA has demonstrated a proven track record with respect to ESC associated with large infrastructure projects. Many of its previous projects have demonstrated the effectiveness of the NZTA's approach, which is based on the consenting authority's approval of CESCPs, or the equivalent, throughout the Project. This track record has been previously illustrated through the NGTR, Hobsonville and the Waterview Tunnel projects.

One of the aims of this Report is to demonstrate and assess the erosion and sedimentation effects that will result from Project construction activity. Discussed within Section 6 are the measures, based on the conceptual construction staging discussed in the construction section of the AEE that we recommend as part of the construction phase of the Project.

As discussed above, we have determined that, from an ESC perspective, the Project can be classified into two distinct types of terrain:

- Flat Country – including the relatively flat areas from Perry Road to Warkworth along the Mahurangi River Right Branch; and
- Hill Country – including the prominent landforms of Pūhoi, Schedewys Hill and Moirs Hill.

To assess the environmental effects related to erosion and sediment yields, two areas of the Project were selected as being representative of the Project as a whole and developed into two Focus Areas as follows, namely Flat Focus Area and Hill Focus Area, as shown on Figure 3.

These two Focus Areas represent the two distinguishing features of the overall construction zone for the Project. Their combined length is approximately 7.5km and represents approximately 40% of the total Project length, and as explained in Section 3 of this Report, we consider the soil properties and geology, slopes and climate in these Focus Areas, with respect to sediment yields, to be representative of the rest of the Project.

We note that due to the Hill Focus Area being within the steeper sections of the Project, that extrapolating this over the rest of the hill country within the Project represents a somewhat conservative approach with sediment yields in practice expected to be less than those predicted.

We have assessed the construction related erosion and sediment related effects of the Project in its entirety, by applying appropriate scaling factors to the modelled results and calculations from the two Focus Areas. This is presented in Section 7 of this Report.

The development of the ESC measures discussed in this Report is based on:

- The conceptual construction programme and staging of works originally developed at the commencement of the Project - The nature of the conceptual construction programme has changed during the preparation of this Report as a result of ongoing design changes. However, from a sediment yield perspective, these design changes are considered immaterial as the same geology and slope characteristics apply and therefore the same issues and conceptual approaches also apply. The ESC measures and practices discussed below provide sufficient information to demonstrate that the sediment yields arising from the construction works can be managed effectively;
- Viewing the construction of the Project in a holistic manner. The combined effects of the construction activity on the receiving environment, are considered as a whole and not in isolation from each other;
- Minimising the potential adverse effects on the receiving environment, by using measures that meet or exceed industry best practice guidelines (TP90);
- The implementation of an integrated management system (as outlined in Section 5.5 of this Report) for the design, implementation, management, maintenance and decommissioning of

ESC measures to ensure appropriate ownership of the CESCPS to provide effective implementation, management, operation and maintenance of ESC devices during construction;

- Developing CESCPS and undertaking pre-construction meetings for specific stages of construction and having regular 'toolbox' meetings onsite with relevant personnel in attendance as part of the construction phase;
- Maintaining a register of control measures and 'As Built' information of key controls such as CWDs, DWDs, DEBs, and SRPs to allow for quick and efficient referencing, identification and understanding of function and location of the various ESC measures installed onsite;
- Ensuring that all ESC measures are structurally sound and have appropriate geotechnical approval or ensuring alternative ESC measures, such as container impoundment systems, are employed;
- Including both Structural ESC Measures and Non-Structural ESC Measures within the ESC methodologies;
- Manually raising decant devices on SRPs and DEBs, as required and, during pumping operations - Pumping will often occur during dry periods and as such the chemical treatment systems will not be activated automatically and manually raising the decants will ensure no discharge from the SRPs or DEBs and will assist with increasing sediment capture during dry weather periods; and
- The development of an adaptive monitoring programme (Section 8 of this Report), to inform the extent and environmental performance of construction activity onsite and directing the work activity to directly influence and reduce the effect of sediment yield into the receiving environment.

5.2 ESC environmental risk

The Project is linear in nature and will involve works occurring on several fronts. The earthworks areas will be subject to ongoing stabilisation as works progress to minimise the potential for erosion and to also achieve the open earthworks area limitations, we have recommended in Section 7 of this Report.

We consider the key elements of construction related environmental risk for this Project to be the exposure of bare land, the steep nature of the topography in sections of the Project, within which earthworks activity be carried out and works within or adjacent to watercourses.

Key sources of this risk are assessed as:

- Works within and adjacent to watercourses and wetlands such as culvert placement, stream diversions and bridge works;
- Cut and fill operations in steep areas; and
- Spoil site establishment and operation.

To assist with an understanding of the nature and magnitude of this risk we have assessed the existing topography, on which we have identified a range of slope classifications throughout the Project footprint.

The slope classifications we have developed are mapped in ES-101 to ES-115 and is summarised in Table 7 in Section 3 of this Report.

As defined in the ARP:SC, 15 degree slopes are considered to be an appropriate point to define areas of high erosion risk. For the Project, those areas with slopes exceeding 15 degrees will be subject to a high level of detailed design and ongoing contractor monitoring, as defined through the adaptive monitoring programme, which will in particular focus on pre-forecast rainfall monitoring and post rainfall monitoring to ensure all controls are in place, have worked as intended and are achieving the required outcomes. The adaptive monitoring programme proposed within Section 8 of this Report supports this approach.

In some areas earthworks activity, within the harder siltstone material, will be required during the winter months, May to September, and we note that there is currently a restriction in place by Auckland Council on working in clay based soils during this period. This winter works restriction will not prohibit the construction, but it will restrict bulk earthworks operations in clay based soils during this historically wetter period of the year.

Construction work within the harder siltstone material can continue during the winter period as this material is less erodible than the overburden material. From an ESC perspective, the natural settlement demonstrated through the chemical flocculation tests undertaken and discussed within the WAFR 2, support the proposal of working within the siltstone material during the winter period.

Overall we recognise the wetter winter period as a higher risk and construction activity within this period will be managed to reflect this higher risk.

As an example of risk assessment for the Project, we highlight the process undertaken by the Further North Project team for spoil site selection. The original spoil site selections were assessed against a range of environmental considerations, such as the location of permanent watercourses, existing vegetation values and the ability to carry out construction and operational water management measures. That process enabled the selection of spoil sites that represent the most appropriate options from an environmental perspective, whilst ensuring risks to the environment are minimised.

As part of the construction phase of the Project the Proactive Risk Approach shown in Figure 11 below will be followed, whereby prior to construction works commencing, the site and associated resources are assessed against a specific risk profile. If a low risk is determined then TP90 guidelines will apply, as a minimum, and if a high risk is determined, then the full suite of both structural and non-structural controls will apply.

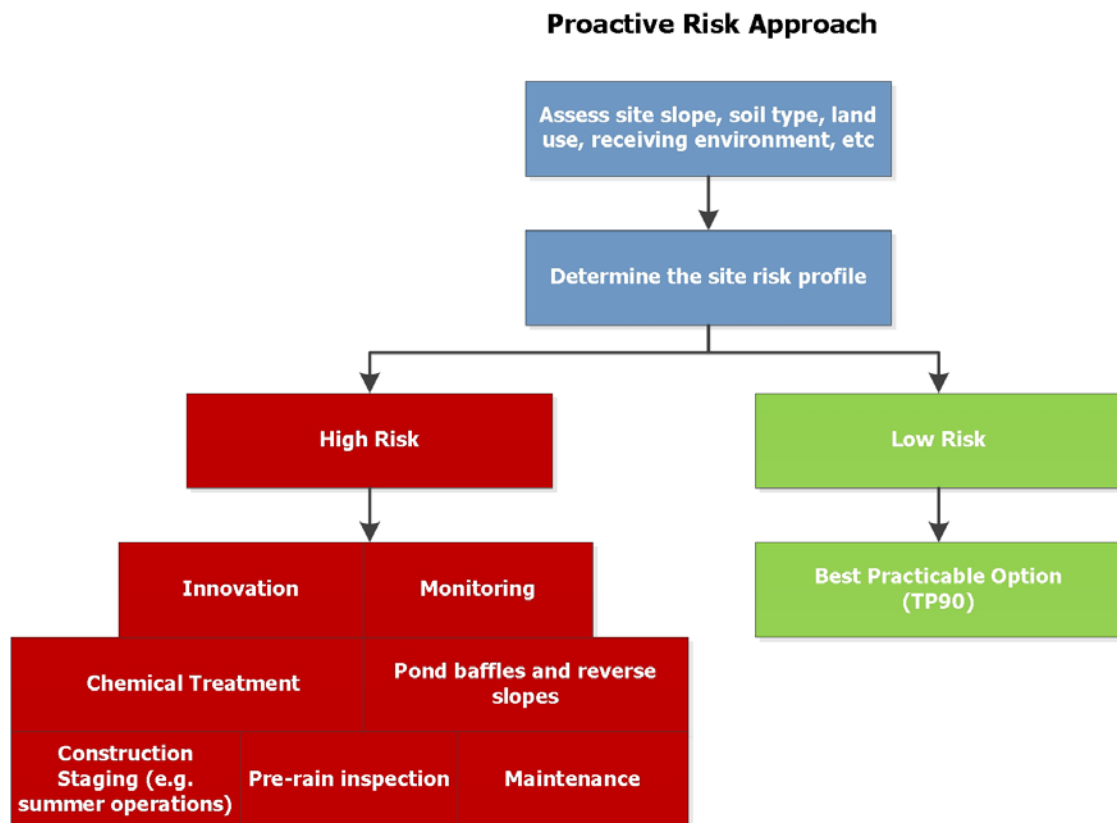


Figure 11: Proactive Risk Approach Framework (Further North, 2013)

5.3 ESC principles and design criteria

ESC measures and practices are used to minimise the effects of earthworks on the receiving environment. In general, steep slopes with long slope lengths, generate a greater amount of energy and hence increase erosion as rainfall lands and runs down a slope. Any reduction of this energy through the use of erosion control measures will reduce erosion and hence any subsequent sedimentation.

We have designed conceptual ESC measures for the two Focus Areas of the Project to take into account the highest level of control and treatment from TP90. We have assessed the relative difference between TP90 and the NZTA draft standard and conclude that TP90 provides the best design approach for the Project while also providing the most practical approach in terms of room availability. In addition, with the introduction of chemical treatment to the design, the retention pond sizes provided for TP90 design are assessed as adequate for achieving the necessary sediment removal efficiencies.

5.3.1 General principles and management techniques

The ESC for the Project will be undertaken and implemented with a hierarchy and priority order as follows:

Prevention: Excluding clean water runoff from entering the active work areas, therefore preventing clean water runoff from combining with excavated spoil and/or construction material and will require the use of clean water diversion (CWD) channels and/or bunds to divert runoff from the upstream side of the work area.

Capture: Any sediment laden runoff generated within the working area will be captured through the use of dirty water diversion (DWD) channels and/or bunds on the downstream side of the construction site, which will direct silt laden runoff from the site to an appropriate sediment control device. Sediment will be captured in one or more sediment control measures.

Minimisation: Limiting the length of time and the area of exposed / disturbed soil to reduce the erosion potential of an exposed area. Timely stabilisation of exposed areas and the construction of impermeable areas will also reduce the potential for erosion to occur.

Staging and Sequencing of Works: Construction activity will be carried out in stages and works within those stages will be sequenced to manage erosion and sedimentation. Working areas will be progressively stabilised as appropriate as the works progress.

5.3.2 Streamwork principles

Streamwork activities are generally considered a higher water quality risk than earthwork activities due to the close proximity of the receiving environment and the associated increased potential for sediment yield. Within the Project, streamworks will be undertaken in a manner that recognises this risk and the sensitivity of the receiving environment.

Where practical, streamwork activities and any associated works will be undertaken in an 'offline' environment. This strategy will primarily be based upon the temporary diversion of flows around the area of works.

In-stream works will generally be restricted to avoid the fish spawning and migration periods (September to February). Where this is not practically possible, fish relocation methodologies will be implemented. Where works need to be undertaken during the main migration period, the section of stream in which the work will be undertaken will be isolated by placing stop-nets at each end of the works section and any fish caught will be relocated within the stream. The lower stop-net will be retained to prevent any fish entering the works area.

5.3.3 Key ESC design criteria

Table 14 below summarises the principles and key ESC design criteria that have been developed for the Project:

Table 14: ESC Principles and design criteria

Device / methodology	Criteria
Erosion control measures	
Clean water diversions (CWD)	Clean water diversion channels and bunds will be designed to cater for the 20 year ARI rain event.
Construction staging and sequencing	Staging and sequencing are both important non-structural measures and will be implemented within the open area limitations. Details of the staging and sequencing of works will be detailed within the CESCPS.
Contour drains	Contour drains will be designed and implemented in accordance with TP90.
Device location	All ESC devices should be located outside the 20 year ARI flood level unless no other viable alternative exists.
Dirty water diversions (DWD)	Dirty water runoff diversion channels will be sized to cater for the 20 year ARI rain event. Sediment sumps will be installed in all diversion channels
Pipe drop structures / Flumes	Flumes will be used in accordance with TP90 to safely transfer runoff from the top to the bottom of the batter slopes.
Rock check dams	Rock check dams will be designed and implemented in accordance with TP90.
Stabilisation for erosion and dust management purposes	<p>Progressive and rapid stabilisation of disturbed areas using top soil (where necessary) and seed, mulch and geotextiles will be ongoing throughout the Project.</p> <p>Stabilisation will be undertaken with three key purposes:</p> <ul style="list-style-type: none"> • To achieve the area of open earthwork limitations as specified within consent conditions for the project; • To reduce the area of open earthworks within higher risk locations to assist with a reduction in sediment generation; and • In response to the adaptive monitoring programme to address any potential effects or undesirable monitoring trends.
Stabilised entrance ways	Stabilised entrance ways will be established at all ingress and egress points of the site from a public road network.
Sediment control measures	
Container impoundment systems	Container Impoundment Systems will be implemented as per Drawing ES-155. They will be based a 3% volume criterion applied in relationship to catchment size and as such will apply to smaller catchment areas. Their primary purpose is for the initial earthworks

Device / methodology	Criteria
	in steep or "difficult" locations prior to the formation of a SRP or DEB structure.
Decanting earth bunds and decant systems	<p>All DEBs established will be based on a volume of 2% of the contributing catchment area. All SRPs and DEBs will be fitted with floating decants.</p> <p>Decants have a mechanism to control (or cease) outflow during pumping activities to these structures.</p>
Flocculation	<p>Flocculation will be applied on all SRPs and DEBs based on an approved chemical treatment management plan and will be applied to all DEBs with a catchment area between 500m² and 3,000m² and all SRPs.</p> <p>Manual batch dosing will be carried out as required.</p> <p>Flocculant socks will be used as alternative and/or additional measures as required.</p>
Sediment retention ponds	<p>All SRPs will be implemented based a 3% volume criterion applied in relationship to catchment size (i.e. 300m³ SRP volume per 10,000 m² of contributing catchment).</p> <p>Baffles, decant pulleys and reverse slopes to be installed in all SRPs.</p>
Super silt fences and silt fences	<p>All super silt fences and silt fences will be based upon the design criteria within TP90. SSF fabric will be installed with 200mm of fabric upslope at the base of the trench.</p> <p>In high risk areas, as identified in Figure 11 of this Report, if a failure of the primary control measure occurs then the last line of defence, the SSF, will capture and treat any discharges.</p>
Other measures / methodologies	
Construction stage erosion and sediment control Plans (CESCPs)	<p>CESCPs will be submitted prior to commencement of work.</p> <p>CESCPs will likely include:</p> <ul style="list-style-type: none"> • Location of the Work; • Contour information; • ESCs; • Chemical treatment design and details; • Catchment boundaries; • Details of construction methods; • Contingency measures; • Design details; • A programme for managing non-stabilised areas; • The identification staff who will manage ESCs; • The identification of staff who monitor compliance with conditions; • A chain of responsibility for managing environmental issues; • Methods and procedures for decommissioning measures; and <p>Design details for managing the discharge of contaminants.</p>

Device / methodology	Criteria
Decommissioning of devices	Removal of devices will be in accordance with the CESC.
Non-structural measures	<p>These elements include:</p> <ul style="list-style-type: none"> Manually raised decant devices on SRPs and DEBs; Batch dosing of SRPs and DEBs with chemical flocculant where required; Proactive monitoring and reporting programme (as per Section 8 of this Report); Risk identification and management accordingly; Progressive stabilisation as works progress; and Weather response.
Pumping activities	Pumping of sediment laden runoff and groundwater during construction will be to SRPs, DEBs to grass buffer zones or to temporary sediment retention devices such as Container Impoundment Systems.
Streamworks	<p>At all practical times these activities, and any associated works within these environments will be undertaken in an offline 'dry' environment.</p> <p>Fish spawning and migration periods will be avoided and managed accordingly.</p>

The design criteria incorporate some procedures and measures that exceed the guidance provided in TP90. Through the design and construction phases of the Project, we recognise that there will be scope for innovation and alternative means of achieving the same environmental outcome as specified in consent conditions.

It is our recommendation that the ESC measures will be planned during the detailed design phase of the Project and constructed onsite and maintained during construction, in accordance with the principles and practices as outlined in this Report.

These principles and practices will also be further detailed and designed within site specific CESCps. The implementation of site specific CESCps will allow for further innovation, flexibility and practicality of approach to construction-related water management and in doing so will allow the construction of the Project to continually adapt to changing construction and climatic conditions.

If the water management measures outlined in Sections 4, 5 and 6 of this Report are implemented, we consider that any sediment yields, resulting from the earthworks and construction activities can be managed with minor effects.

Both TP90 and the NZTA guideline documents place emphasis on a number of principles that apply to ESC. These principles have also been considered and have informed the development of the principles for this Project. Appendix A contains both TP90 and the NZTA guideline principles.

The Project will be subject to an adaptive monitoring programme as detailed within Section 8 of this Report.

Conceptual design drawings for the ESCP are provided as the 'ES' series in the Project drawing set.

5.4 Innovation

Section 4 of this Report outlines the nature of the ESC measures that will be used within the Project. We note that the ESC design is based on TP90 however in many circumstances the design and implementation of ESC measures will go beyond TP90. As such these measures are referred to within this Report as innovative measures.

5.4.1 Long Bay development innovation

We reference the Long Bay development³ within the Auckland region, which has been subject to earthworks over three earthworks seasons between 2010 and 2013 and at the time of writing this Report is ongoing. The Long Bay development is taking place in relatively steep, clay based terrain and has a marine reserve as its receiving environment.

With the emphasis on ESC, the Long Bay development has included the implementation of a number of innovative structural and non-structural ESC measures, including:

- **Structural**
 - SRP Baffles;
 - SRP reverse slopes in base of ponds;
 - SRP decant pulleys;
 - Sediment sumps in all diversion channels;
 - Installation of a last line of defence for all erosion and sediment controls; and
 - Rainfall activated flocculation devices for:
 - DEBs with a catchment area of between 500 and 3,000 m²; and
 - SRPs with a catchment area greater than 3,000 m² with double flocculation sheds.
- **Non-Structural**
 - Manual batch dosing of SRPs and DEBs with chemical flocculants during pumping operations;
 - Email and SMS notifications for ESC site and management staff in response to forecast rain events;
 - Significant pre, during and post rainfall inspections;
 - Educational 'Toolbox' meetings for all site staff on ESC measures; and
 - Implementation of an adaptive monitoring programme including:
 - The continuous sampling and testing of water samples from selected SRP discharge locations;
 - If elevated levels of sediment are found within the samples, then site based investigations are carried out to determine the cause; and

³ Long Bay development is a residential development on the Auckland North Shore currently subject to cut to fill earthworks activity.

- Once the cause of elevated sediment levels has been determined, corrective actions including additional chemical dosing, restrictions on earthworks activity and stabilisation of open areas with mulch.

Table 15 shows the results of the laboratory analysis carried out on the water quality samples taken for the Long Bay development during the earthworks season from October 2011 to May 2012. This table confirms the sediment yields from the associated earthworks and illustrates the success of the erosion and sediment control measures used, which were assessed as highly effective.

Table 15: Long Bay development laboratory test results

Month	SRP A (t of sediment)	SRP A1/A2 (t of sediment)	SRP B (t of sediment)	SRP F1/F2 (t of sediment)	Total/Comments (t of sediment)
September 2011	0.09	NA	NA	NA	0.09
October 2011	0.03	0.01	0.24	NA	0.28
November 2011	NA	0	0.047	NA	0.047
December 2011	NA	1.79	0.29	0.08	2.16
January 2012	NA	0.09	NA	0.28	0.37
February 2012	NA	0.003	NA	0.005	0.008
March 2012	NA	0.24	NA	0.17	0.41
April 2012	NA	0.006	NA	0.014	0.02
May 2012	NA	0.09	NA	0.099	0.189
2011/2012 Total Automated SRP Sediment Yield (t)					3.574

USLE calculations for the Long Bay development for the same 2011/2012 earthworks season equated to approximately 43.8t from a 20.2ha earthworks area.

Nine rainfall events with 25mm or greater rainfall depth over a 24 hour period were recorded during the 2011/2012 earthworks season, all of which were recorded as being less than a 2 year return frequency. During these events there was pre, during and post storm event management, manual management of the SRPs including the raising of decants and ongoing checks of all discharges. The implementation of these measures has resulted in ongoing improvements to the ESCs and has resulted in actual sediment yields being significantly less than those modelled through the original USLE calculations.

5.4.2 Further North Alliance – Project innovations

The following outlines what the Further North Alliance ESC team considers to be innovative practices and lessons learned from other projects in relation to the establishment of ESC measures and practices.

We recommend that many of these practices should be used on the Project, and recognise that these innovative practices do not currently fall within the current recommendations of TP90.

Innovation to be employed throughout the Project includes:

- **Learning from Long Bay development**

Structural

- SRP Baffles;
- SRP reverse slopes in base of ponds;
- SRP decant pulleys;
- Sediment sumps in all diversion channels;
- Installation of a last line of defence for all erosion and sediment controls; and
- Rainfall activated flocculation devices for:
 - DEBs with a catchment area of between 500m² and 3,000 m²; and
 - SRPs with a catchment area greater than 3,000 m² with double flocculation sheds.

Non-Structural

- Manual batch dosing of SRPs and DEBs with chemical flocculants during pumping operations;
- Email and SMS notifications for ESC site and management staff in response to forecast rain events;
- Significant pre, during and post rain inspections;
- Educational 'Toolbox' meetings for all site staff on ESC measures; and
- Implementation of an adaptive monitoring programme including:
 - The continuous sampling and testing of water samples from selected SRP discharge locations;
 - If elevated levels of sediment are found within the sample, then site based investigations are carried out to determine the cause; and
 - Once the cause of elevated sediment levels has been determined, corrective actions including additional chemical dosing, restrictions on earthworks activity and stabilisation of open areas with mulch.

- **Stabilisation trials early in construction process**
 - Conduct stabilisation trials early in the construction process on various cut and fill locations (including monoslopes) and monitor the results of the water quality sampling (as per Section 8 of this Report) to establish a direct link between earthworks activity, stabilisation techniques and their direct effect on sediment yields.
- **Container impoundment systems**
 - In areas where it is especially difficult to establish a permanent SRP or DEB through difficult terrain, geotechnical reasons or restrictions on working room within a particular work area a container impoundment system (CIS) can be used. Drawing ES-155 indicates the typical arrangement of a CIS.
- **Flocculant socks**
 - Flocculant socks are filter socks which contain bark or other material which has been impregnated with chemical flocculant; they are typically placed within diversion channels; and as water flows through them, it reacts with the chemical flocculant, allowing treatment of the runoff. They are particularly useful in treating sediment laden discharges from pumping operations.
- **Consenting authority approval protocol**
 - We recognise that many of the ESC practices discussed in this Report go beyond the requirements of TP90 and we would seek approval as necessary through discussion with the Consenting Authority to implement the ESC systems and practices on the Project that are not currently included within the guidelines, recommendations and standard practices contained within TP90.

While we consider that innovation will apply to all earthworks activity, those activities with an identified higher risk profile will be subject to more stringent management of both structural and non-structural measures.

To ensure the identified ESC approaches and innovative practices are appropriate and applicable, we discuss in Section 6 below the specific ESC measures that can be applied on the Project.

5.5 Integrated management system

An integrated management system will be established which will ensure that appropriate resources, commitment and expertise are provided for the ESC aspects of the Project from the planning, design and construction phases and will ensure that relevant key stakeholders are involved in the development of the ESC measures and practices onsite and the objectives are communicated.

The reduction in the potential for erosion and subsequent sediment yields will depend on the timely establishment of ESC measures, implementing appropriate ESC management practices during construction and land disturbance activities through to the stabilisation of disturbed ground.

Successful stabilisation of disturbed ground will largely depend on the establishment of motorway pavement and permanent planting. The timing of the construction works will also take into account the permanent landscaping requirements for the Project.

As part of the Project implementation, we expect that the CESCPS will follow the conceptual principles and details outlined within this Report and will also enable the construction team to have ongoing input into the ESC measures and practices prior to and during construction.

The integrated management system is a process based approach which will broadly follow the principles outlined within Section 5 of this Report and will include:

- Education and Training of all site staff - All staff working onsite, or with site responsibilities, shall undertake a formal site induction which will include an ESC module to ensure familiarisation with the requirements of TP90, the principles of the Draft NZTA Standard and the content of this Report. No-one will be permitted to work on the site until they have completed the site induction process;
- Implementation of an adaptive monitoring programme which will be developed to inform the extent of construction activity onsite and directing that activity to influence and reduce the direct effect of construction works on the sediment yield into the receiving environment;
- Development of CESCPS
- Quality Assurance / Management System – Develop a system for identification of ESC devices to:
 - Provide written records of the management and maintenance programme for ESC devices; and
 - Ensure awareness of the reporting procedure in the event of defects being discovered.
- Proactive and reactive ESC maintenance
 - **Proactive Maintenance**
 - Undertake Regular – (Daily, Weekly and Long-range) - weather monitoring;
 - Programme construction works and stabilisation works in response to weather forecasts;
 - Regularly remove accumulated sediment from ESC devices and make necessary repairs to ESC devices prior to forecast rainfall events; and
 - Undertake pre and post rainfall event inspections of ESC measures.
 - **Reactive Maintenance**
 - Repair any defective or damaged ESC measures following rainfall events;
 - Record the location of any sediment laden discharges to the receiving environment during a rainfall event; and
 - Develop a coordinated response plan in the event of unplanned sediment laden discharges to the receiving environment including:

- Cessation or reduction of work activity in a particular area until accumulated or deposited sediment can be removed and the ESC measures can be repaired or replaced;
- Remedy the effects of any sediment laden discharges, if required; and
- Monitor the effects of any sediment laden discharges.

5.6 Alternative methodologies considered

In this Report we have demonstrated our proposed methodologies and management techniques for construction water management. Prior to selecting the methodologies discussed above, we considered the following alternatives for reduction of sediment generation and other contaminants associated with the Project:

Construction period – The sediment generation from two conceptual construction periods (5 years and 10 years) was assessed using GLEAMS modelling and the USLE model, as explained in Section 7 of this Report, to determine whether sediment yields could be reduced by extending the construction period.

We then compared the predicted increase in total sediment yield in the Mahurangi River and Mahurangi Harbour (as shown in Table 23 and Table 24 below) for both the 5 year and 10 year conceptual construction programmes.

Our analysis shows that there is a predicted decrease of only 1% in sediment yields in the Mahurangi River and a decrease of 0.5% in sediment yields in the Mahurangi Harbour when changing from a 5 year to a 10 year construction programme. We have therefore assessed that an extended construction programme does not result in a significant reduction of sediment yields to the Mahurangi River or Mahurangi Harbour during construction.

Flocculation – As discussed in Section 4.5.6 of this Report, we have considered alternative ESC measures and practices and given the restrictions of working room, especially in the Hill Country, and through the inclusion of learnings and experience gained from the Long Bay Development, we recommend the use of flocculants to increase sediment retention within the ESC devices.

We also undertook a series of flocculation tests on physical soil samples collected from the Project and arranged for these to be laboratory tested to assess the effectiveness of a range of flocculants on these soil samples and to confirm that there are a number of commercially available flocculants that will work on the soils that are expected to be encountered during construction. The results of the flocculation testing are discussed in WAFR 2.

Devices for the steep areas – SRPs and DEBs are the primary sediment control devices to be used as shown in the conceptual ESC (see Drawings ES-001 to ES-025). Where it is found that there is limited working room to establish SRPs and DEBs during construction we have considered the use of CISs as discussed in Section 4.5.4.

Discharge locations – We have identified a number of locations where sediment retention devices will discharge to the freshwater environment. We have discussed the development of site

specific CESCPS, which will consider the ecological values of the receiving environment and the effect on, and avoidance of, discharging in the vicinity of existing water takes from the Mahurangi River.

Through the development of the specific assessments for the Project there have been a number of iterations of the design and alignment of the Project. Construction assessment has formed part of this process whereby issues and options have been identified and the indicative alignment and proposed designation have been adjusted to reflect this assessment process.

6. Management of construction activities

Construction Water Management Methodologies

Specific ESCPs have been developed for the two ESC Focus Areas and for a number of particular construction activities.

Specific activities for which these construction water management techniques have been developed include:

- Vegetation removal;
- Stockpile and Spoil site establishment;
- Temporary and permanent stream diversions;
- Pumping activities;
- Culvert installation;
- Bridges and viaducts;
- Concrete work;
- Chemical treatment;
- Rip rap placement;
- Haul road establishment;
- Construction yards; and
- Monoslopes.

The construction water management techniques outlined are considered conceptual and while they are based on a specific activity or an area of the Project, they have the primary purpose of illustrating that the ESC methodologies can be carried out within the Project footprint.

Conditions of consent are recommended which provide confidence that the ESC measures and associated outcomes can be achieved for the Project construction.

Water Quality Assessment Methodology

To characterise existing water quality, we have supplemented Auckland Council's water quality information with a baseline monitoring programme, designed to gather additional information on the Project catchments. We have used both data sets to describe the existing water quality and improve our understanding of the existing values and uses of water within the Project and the surrounding area.

We then considered the design of the Project, including the conceptual water management measures proposed to reduce the potential effects of the discharge of sediment and contaminants during the construction phase.

We have used our understanding of the existing environment, the conceptual design and water management measures to help us predict any change in the existing water quality resulting from construction activity. This was based on the results of the GLEAMS and a harbour sediment and transport modelling exercises.

The results of the sediment modelling exercises were used to consider the effects of the Project on existing water quality and the existing values and uses. The water quality assessment is focused on effects on:

- Change in water quality;
- Aesthetics and odour;

- Human health and amenity; and
- Water users.

The effects on ecosystems are discussed in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

6.1 Construction activity specific methodology

This section includes the details of ESC measures and practices required to manage construction-related stormwater runoff from the various construction activities on the Project.

The works methodologies discussed below are conceptual in nature and a detailed description of the works, required to manage erosion and sedimentation during the construction phase for the various construction activities discussed below, will be further developed and detailed within the CESCPS. CESCPS will be produced by the Principal Contractor prior to construction works commencing.

We note however that we have 'tested' the methodologies within specific locations of the Project to ensure practicality and workability and have also assessed that these methods can be transferred to the same activity type within other locations within the Project.

This has further been assessed within the context of potential conditions of consent which will ensure such methodologies apply and achieve the same environmental outcome as those 'tested'.

6.1.1 Vegetation removal

The removal of vegetation (mainly exotic pine plantation) is required on the Project. Auckland Council Technical Publication TP223 (based on Best Management Practices (BMPs)) will apply for these activities, which are practices primarily intended for use by those directly involved in undertaking or managing forestry operations.

The vegetation removal will effectively form part of the overall land disturbing activity that needs to be undertaken for the Project, and it is the first of many steps that will occur. While the vegetation removal itself does not include earthworks activity there may be a number of associated earthworks activities such as tracking and skid site establishment and haul road construction. Vegetation removal is a permitted activity in accordance with the ARP:SC.

Prior to undertaking vegetation removal, appropriate ESC measures will be installed that will apply to the subsequent earthworks operation. The removal of vegetation will result in some areas of initial disturbance that will be the subject of progressive stabilisation, using mulched tree vegetation, while diversion channels and retention structures are established. If vegetation removal is required as a standalone activity, then specific CESCPS will be developed

The vegetation removal component of the Project is a relatively short-term activity and the specific control measures to be employed will be fully detailed and designed within the CЕСPS for specific locations. We assess that the vegetation removal operations that will occur throughout the Project will all be subject to the CЕСPS process and this will provide an appropriate level of control.

6.1.2 Acid sulphate soil management

Acid sulphate soils (ASS) are natural soils that are rich in iron sulphide minerals. ASS have the potential to release acid and toxic concentrations of metals that can lead to environmental and infrastructure degradation.

ASS are stable while they remain in a low oxygen environment. However, their disturbance can cause them to oxidise, producing sulphuric acid and mobile metal ions. Exposure of ASS commonly occurs when the water table is lowered, soils dry out or excavation is undertaken.

The presence and extent of ASS will be confirmed through further investigations during the detailed design stage of the Project and the locations and mitigation measures proposed will be identified and included in an Acid Sulphate Soil Management Plan, which will in turn assist with the development of the CESCPS prior to construction commencing.

6.1.3 Stockpile establishment and management

A stockpile is a temporary store of material that is placed and stored prior to re-use or disposal. The majority of materials to be stockpiled on the Project will be topsoil, subsoil, unsuitable material -gained from the bulk earthworks operations - and hardfill material such as crushed rock. It is anticipated that imported hardfill will also be stockpiled.

Stockpiles can become a source of sediment and dust and will need to be carefully managed to ensure there are no environmental effects resulting from these areas.

Stockpiles will be established throughout all sectors of the Project, the major ones being for the storage of topsoil and subsoil material for re-use during the establishment of the permanent landscaping for the Project. Surplus material and soil that is unsuitable for the construction of embankments will be disposed of in one of the identified spoil sites within the proposed designation. The identified spoil sites are discussed in Section 6.1.4 of this Report.

The establishment of stockpiles will be subject to the development of CESCPS. From an ESC perspective, the establishment of material stockpiles will have regard to the following to reduce the risk of sediment-laden runoff from entering the receiving environment.

- **Water pollution**

- All care and due diligence will be taken to minimise or prevent pollutant material entering waterways and stockpiles should not be established below the level of the 20 year ARI flood extent;
- Stockpiles should not be established within 20 m of a permanent watercourse; and
- CWDs will be established on the 'high' side of the stockpile to direct upslope runoff away from the stockpile area. These CWDs will prevent erosion of the base of the stockpile, which could affect the stability of the stockpile and induce a slip within the stockpiled material.

- **Soil disturbance and erosion**

- ESC measures will be implemented and maintained to prevent sediment from leaving the site. SSFs or DEBs will be provided on the 'low' side of the stockpile to ensure any sediment-laden runoff from the surface of the stockpile is treated prior to discharge;
- Material stockpiled for longer than one month will be stabilised using vegetative mulch or geotextile; and
- Stockpiles will not be established on ground with a slope greater than 5% unless a geotechnical assessment has confirmed suitability of the site for such a purpose.

- **Dust management**

- Any vehicle transporting materials to be stockpiled, that may produce dust, will be managed to minimise dust during transportation; and
- Water will be sprayed on stockpiles from water carts to suppress dust during the construction period as necessary.

The specific location of temporary stockpiles has not been determined on the Project and will be confirmed and outlined within the CESCPS. As part of the site visits undertaken and the assessment process, we have determined that there is adequate room available for stockpiles within the proposed designation, and that the above measures will be adequate to ensure effects of runoff from these features are minor.

6.1.4 Spoil site establishment and management

The construction section of the AEE confirms that unsuitable and surplus material will be cut from the various cuttings zones within the Project and disposed of within various spoil sites and embankment widening works associated with the Project. The locations of the areas identified for the deposition of unsuitable material are indicated on Drawings ES-001 to ES-025.

The final spoil site locations and final volumes are yet to be confirmed for the Project. Clearly from a construction perspective a large degree of value engineering will need to occur prior to construction, which will significantly reduce the spoil volumes. We assess however that irrespective of the spoil volumes, from an effects perspective, the open area of earthwork limitations that will be imposed on the earthworks will remain, and therefore sediment yield effects will continue to be within this envelope.

Conceptually the ESC measures required during the establishment and management of the spoil sites will be similar to that required for the establishment of the various cut and fill zones proposed throughout the Project. The various activities would likely be as follows:

- Haul Road and access road construction – (Discussed in Section 6.1.11 of this Report);
- Clearing vegetation and stripping of topsoil (Discussed in Section 6.1.1 of this Report);
- Temporary and Permanent Stream Diversions (Discussed in Section 6.1.5 of this Report);
- Construction of Gully drains;
- Construction of shear keys (Discussed in Section 6.1.7(c) of this Report);

- Stockpiling of excavated material;
- Bulk Earthworks (Excavation and Filling operations);
 - Cut to Fill within the Site
 - Import of cut material to disposal site
- Drying / Dewatering of unsuitable material; and
- Pumping of groundwater and surface water runoff (discussed in Section 6.1.7(c) of this Report).

The establishment and management of spoil sites will require site specific CESCPS to be prepared prior to works commencing within the spoil site areas. To demonstrate that erosion and sediment can be managed effectively during the establishment of the spoil sites we have developed a conceptual ESCP for indicative Spoil Site 10 which is discussed below.

(a) Spoil Site 10 – Conceptual ESCP

Indicative Spoil Site 10 is a 10 ha site located to the north-east of Moirs Hill (between CH 55350 and CH 55700). Approximately 1.5 M m³ of unsuitable material may be deposited within this area.

Due to existing unstable ground conditions, 3 shear keys are proposed to support the road embankment along with a spoil bund, which is required to retain deposited spoil within the spoil site.

A conceptual design of the spoil site, shear keys and road embankment through this area can be found on Drawing ES-094 (A conceptual ESCP for Shear Keys is discussed in Section 6.1.7(c) of this Report).

Following the development of this design, the Further North ESC Team developed a conceptual ESCP for the establishment of the spoil site, which includes a conceptual staging of works required to establish and manage the formation of the spoil site, shear keys and road embankment. Drawings ES-091 to ES-095 indicate the various stages, which are described as follows:

Stage 1 (Drawing ES-091)

- Establish an access road to the location of culvert 55300;
- Clear vegetation from the culvert location and permanent stream diversion channel only;
- Construct a CWD (A1) above the culvert location to prevent run-on water from the uphill catchment from entering the work area;
- Establish DWD and DEB (B) to receive pumped flows from culvert excavation works;
- Construct the permanent stream diversion (C1) downstream of the culvert location:
 - Construct any permanent erosion protection measures and stabilise the channel;
- Construct Culvert 55300:
 - Pump any ground water and surface water flows from within the works to the DEB (B);

- Construct a CWD (A2) and the permanent stream diversion (C3) upstream of the culvert location around the perimeter of the spoil site location;
 - Construct any permanent erosion protection measures and stabilise the stream diversion channel; and
 - Once the channel has been stabilised the CWD (A1 and A2) can be decommissioned.

Stage 2 (Drawing ES-092)

- Clear the vegetation from Area (E) only;
- Construct the CWDs (F) to redirect stormwater runoff from the upstream catchment around the works area;
- Construct the SRP 1;
- Construct DWD within the work area and discharge to SRP 1, pumping of groundwater and surface water flows will be required during the construction of the gully drains, pumped flows will be discharged to SRP 1;
- Construct Gully Drains in Area (E);
 - Excavated material to be placed and spread within the spoil site uphill of the work area stabilised with mulch at the end of each working day;
- Clear Vegetation from Area (H);
- Construct the CWDs (G) to redirect stormwater runoff from the upstream catchment around the work area;
- Construct SRP 2;
- Construct DWD within the work area and discharge to SRP 2, pumping of groundwater and surface water flows will be required during the construction of the gully drains, pumped flows will be discharged to SRP 2;
- Construct Gully Drains within Area (H);
 - Excavated material to be placed and spread within the spoil site uphill of the work area stabilised with mulch at the end of each working day;
- Completed sections of gully drains within both work areas to be stabilised at the end of each working day.

Stage 3 (Drawing ES-093)

- Clear the vegetation from Area (I) only;
- Construct the CWDs (J) to redirect stormwater runoff from the upstream catchment around the works area;
- Construct SRP 3;
- Construct DWD within the work areas and discharge to SRP 3, pumping of groundwater and surface water flows will be required during the construction of the gully drains, pumped flows will be discharged to SRP 1;

- Construct gully drains in Area (I);
 - Excavated material to be placed and spread within the spoil site uphill of the work area stabilised with mulch at the end of each working day;
- Completed sections of gully drains within the work area to be stabilised at the end of each working day.

Stage 4 (Drawing ES-093)

- Clear the vegetation from Area (K) only;
- Construct the CWDs (L) to redirect stormwater runoff from the upstream catchment around the works area;
- Construct DWD within the work areas and discharge to SRP 3, pumping of groundwater and surface water flows will be required during the construction of the gully drains, pumped flows will be discharged to SRP 3;
- Construct Shear Key beneath Spoil Bund in Area (K);
 - Excavated material from the shear key is to be placed and spread in Areas (E) and/or (H), the DWD in Areas (E) and (H) are to be maintained and the flows directed to SRPs 1 and 2 respectively during the construction of the Shear Key works; and
 - Stabilise deposited material with mulch at the end of each working day, or when rain is forecast.

Stage 5 (Drawing ES-094)

- Clear vegetation from Area (L) and stabilise the area with mulch;
- Extend the discharge pipework from SRP 3 to the existing stream existing watercourse;
- Erect Super Silt Fence (M) across the gully downhill of Shear Key locations;
- Construct the Shear Keys west of the proposed road alignment;
 - Excavated material from the shear key excavation is to be placed and spread in Areas (E) and/or (H), DWDs in Areas (E) and (H) to be maintained and the flows directed to SRPs 1 and 2 respectively during filling works;
 - Stabilise deposited material with mulch at the end of each working day, or when rain is forecast;
- Pump groundwater and surface water runoff from the shear key excavations to SRP 3;
- Construct gully drains through and downstream of the shear key locations;
 - The excavated material from the gully drain construction is to be placed and spread in Areas (E) and/or (H), DWDs in Areas (E) and (H) to be maintained and the flows directed to SRPs 1 and 2 respectively during filling works;
 - Stabilise deposited material with mulch at the end of each working day, or when rain is forecast;
- Upon completion of the shear keys and the work area stabilised with mulch, SRP 3 can be decommissioned.

Stage 6 (Drawing ES-094)

- Construct up to Level 1 of the spoil bund and stabilise the surface area with mulch upon completion;
- Construct SRPs 4 and 5;
- Clear the remaining vegetation uphill of the spoil bund:
 - Construct DWDs within the cleared area and discharge sediment laden runoff into SRPs 4 and 5;
- Commence filling operations behind the spoil bund until Level 1 is reached;
 - The filling operations will require that the DWDs within the works area are adjusted and moved throughout the filling operation;
 - Stabilise open areas with mulch as required.
- Once Level 1 of filling operations is complete, commence filling operations for Level 2 of spoil bund construction and repeat until area behind spoil bund is filled. (Levels 3 to 4);
 - The adjustment of the DWDs within the fill area behind the spoil bund will be constantly monitored to ensure that sediment laden runoff is discharged to SRPs 4 and 5.

Stage 7 (Drawing ES-095)

- Clear remaining vegetation to the west of the road alignment and construct SRP6;
 - Open areas of cleared ground will be as required.
- Construct DWDs within area (N) and discharge to SRP 6;
- Establish CWDs (O) uphill of the embankment footprint; and
- Commence construction of road embankment and stabilise with mulch as required.
 - Runoff from the road embankment to be discharged to SRP 6.

Stage 8 (Drawing ES-095)

- Construct DEBs (P) at base of road embankment;
- Decommission SRP 6;
- Commence filling of embankment face with Landscape buttress fill and progressively stabilise with mulch:
 - Once filling works are complete stabilise with topsoil and establish permanent planting;
- Once area is stabilised and planting is established, decommission the DEBs (P).

It is expected that site specific CESCPS will be produced for the establishment and management of the spoil site during construction works.

All works are effectively outside of the stream channel alignment with this in itself acting as the key to ensuring effects are minimised. The conceptual construction sequence discussed above is a description of only one possible method of establishment of this spoil site and we have

demonstrated that it can be managed effectively to control the effect of erosion and subsequent sedimentation.

6.1.5 Temporary or permanent stream diversions

Stream diversions will be required during the construction of the Project to divert flows on a temporary basis to allow construction works to progress or provide access to an area. They are also required on a permanent basis to divert the stream around or through a permanent feature of the Project, such as an embankment, bridge or culvert. In both temporary and permanent cases, the stream diversion will be necessary in order to establish an 'off-line' environment to allow construction works to be completed outside of the active stream channel.

A large number of the existing streams are intermittent, as outlined in the Freshwater Ecology and Operational Water Assessment Reports. While stream diversions will be used to undertake works within these intermittent streams, the overall risk is greatly diminished. We also note that when fish migration periods cannot be avoided, fish recovery methodologies including fish relocation will be implemented as outlined in the Freshwater Ecology Assessment Report.

The following discusses a conceptual sequence of works required to complete a temporary or permanent stream diversion:

- Excavation of the diversion channel will be carried out offline from the existing stream, so that excavation works can be carried out in a dry environment. A clay plug will be left in place at each end of the diversion channel to ensure that the existing stream cannot breach and flow through the new channel prior to it being stabilised:
 - The dimensions of the diversion will be such that it will have sufficient capacity to cater for the 20 year flow, in accordance with TP90. This will be detailed within the CЕССР; and
 - Where the capacity of the diversion differs from the TP90 requirements this will be explained and justified within the CЕССР.
- Stabilisation of the newly constructed diversion channel will be carried out to ensure it does not become a source of sediment. This will be achieved using geotextile fabrics, rip rap material or rock armour;
- Once the diversion channel is fully stabilised, the downstream clay plug will be removed to allow stream flows to enter the diversion channel. The upstream clay plug can then be removed allowing stream flows through the diversion channel;
- Removing the downstream clay plug first helps to reduce scour in the diversion channel by keeping some water within it when the upstream plug is removed;
- A non-erodible dam will then be placed within the original channel immediately downstream of the inlet to the diversion channel in order to divert flows into it. A non-erodible dam will also be immediately placed at the downstream end of the original channel, upstream of the diversion channel outlet to prevent backflow into the construction area. Once the flows have been diverted and the dams placed, fish removal from the original channel can be completed. Construction activity can then take place within the original channel as required;

- The non-erodible dam will comprise the formation of a sand bag barrier with an impermeable lining to avoid seepage through the sand-bags. Clay will then be placed immediately behind the sand-bags to prevent water flowing through the sand-bag barrier and into the construction area;
- Any water remaining within the original stream channel and works area will be pumped to a DEB. Pumped volumes will be minor and the decant within the DEB will be manually raised during the pumping process to allow for settlement of sediment and chemical treatment with flocculant if necessary;
- Once the original channel has been de-watered, construction activity – including the removal of weak and unsuitable material, filling, culvert construction, etc. – within the original channel can then occur;
- While it is considered unlikely to be required, if necessary, CWDs will then be installed above the area of work to ensure that stormwater runoff from the existing catchment outside of the works is excluded from the area during the construction period;
- Material excavated from the diversion channel will be placed in stockpiles away from the stream diversion and outside of the identified flood plain area;
- Although the works will not commence until a fine weather window is forecast, geotextile material will be available onsite to cover any exposed areas and stockpiles;
- The works will be staged such that if flood conditions result the area can be fully stabilised in a few hours. Any sediment deposited within the newly formed channel will then be pumped to a DEB;
- Once the works within the original channel have been completed, other appropriate controls, such as silt fences, will be installed below the area of works; and
- Once the new culvert has been constructed and the surrounding area stabilised then flows from the existing to the new channel and culvert can be transferred.

If rainfall occurs during the course of construction (refer to Section 7.1 of this Report) this will be managed as below. In the event of forecast rainfall, or before leaving the work area for more than 24 hours the following will occur:

- Any loose material that could enter a watercourse is to be removed from the work area, depending on the quality of the material this will be either to a spoil site or to a stockpile area;
- Where possible, all exposed areas will be covered with geotextile to ensure no flows overtopping the stream banks create scour issues. It is expected that this will be achieved through geotextile with the geotextile appropriately trenched in at the head and toe of the area;
- All existing and additional erosion and sediment control measures will be inspected, secured and maintained where required;
- Additional mulch and geotextile / polythene will be kept onsite at all times to cover exposed areas and stockpiled material; and
- Extended working hours will be considered if it is of significant benefit with regard to programme and environmental impact.

Where the pumping of flows around the work area is required this will be carried out in accordance with the methodology described in Sections 6.1.6(a) and 6.1.7(c) of this Report.

(a) Kauri Eco Viaduct stream diversions (Drawings ES-051 and ES-052)

The construction of the Kauri Eco Viaduct, to the west of the Genesis Aquaculture facility, will require a permanent stream diversion of a section of a tributary of the Mahurangi River Right Branch to be established prior to construction works commencing on the establishment of road embankments and construction of the structure beneath the proposed road embankment. (Drawings ES-051 to ES-052 indicate the conceptual ESCP for this Culvert).

From an ESC perspective the main issue that requires focus for this stream diversion is the sequencing of the works, ensuring that work is completed in the minimum amount of time possible and that works directly adjacent to existing streams are carried out carefully. The two stages of works as outlined below provide the conceptual methodology that will apply to these works.

Stage 1 (Drawing ES-051)

- Establish a CWD (A) to the west of the work area
- Establish a section of the permanent stream diversion (B) and stabilise. Once the channel is stabilised transfer flows at point (C) from the existing stream into the new stream diversion.
- Place sand bag barriers at points (D) to ensure flows from the tributary to the west flows into the new stream channel and to isolate the channel to prevent backflow from the existing channel flowing from the south and to enable fish recovery.
- Inspect the isolated section of the existing channel (E) and if required recover any fish from this section and relocate in accordance with Freshwater Ecology Assessment Report; and
- Once fish recovery operations have been completed, dewater the isolated section of channel by pumping to the SRP or CIS, which will be batch dosed with chemical.

Stage 2 (Drawing ES-052)

- Establish a CWD (F) to the west of the permanent stream diversion.
- Construct the permanent stream diversion (G) to the west of the alignment following the same procedure discussed in stage 1. Install clay plugs until the permanent stream diversions have been stabilised;
- Once the channels have been confirmed as being stabilised from an ESC perspective, the clay plugs can be removed and flows can be directed into the permanent stream diversion;
- Place sand bag barriers in the existing channels;
- Inspect the isolated sections of the existing channel and if required recover any fish from these sections and relocate in accordance with the Freshwater Ecology Assessment Report; and
- Once fish recovery operations have been completed, dewater the isolated sections of channel by pumping to the SRP or CIS.
- Once the original channels have been dewatered, vegetation can be removed from these sections of channel and unsuitable material can be removed from the channel and transported to the spoil sites via haul road; and
- Once all unsuitable material has been removed filling of the original stream channels can be carried out as necessary.

The conceptual construction sequence discussed above is a description of only one possible method of construction and we have demonstrated that it can be managed effectively to control erosion and sedimentation.

6.1.6 Culvert construction

Temporary and permanent culvert construction will be required in a number of locations throughout the Project. Temporary culverts will be provided to allow construction vehicles to cross watercourses and overland flowpaths, and these will be removed when no longer needed.

As with the stream diversion methodology discussed above it is important that the culvert construction activities are undertaken early in the construction program to ensure that the surrounding earthworks can be completed within these areas.

Fish migration and spawning seasons are important considerations to take into account during the construction of culverts and stream diversions, these are addressed in the Freshwater Ecology Assessment Report. We note however that from a construction and operational perspective that as soon as the culvert is commissioned and stream flows are directed through the culvert then the operational considerations apply. The operational component of the culvert includes verifying that long term fish passage remains and that the hydrological design aspects of the Project are fully addressed.

Prior to undertaking the works at a particular culvert location, a specific construction methodology will be developed and will be detailed within the CESCOP for the particular location.

Culverts will generally be constructed within an offline location, isolated from the existing stream flows. A stream diversion will be required either prior to construction works commencing on the culvert or to direct flows into the culvert once construction works have been completed.

Where culvert installation or an extension is required within a stream channel, and it is not possible to divert the stream, the culvert works, depending on stream flows and fish passage requirement (the Freshwater Ecology Assessment Report provides for fish management measures) could be carried out either by bypassing the flows around the culvert footprint by establishing a stream diversion as discussed in Section 6.1.5 of this Report or by pumping the flows around the culvert works areas as described below. Figure 12 below illustrates culvert construction from the NGTR including the associated stream diversion.



Figure 12: Completed NGTR culvert construction

(a) Pumping of stream flows around the culvert work area

Pumping of flows from an existing stream will only be carried out in situations where it is not practical to construct a diversion channel. The decision to pump as opposed to the installation of a diversion channel will be made by the Project team, and will form part of the CЕСP for that construction work area.

This methodology and associated process is a common approach to works in stream channels and has been used successfully on the NGTR and Long Bay developments.

Where pumping is to occur the operation will be carried out as follows:

- Place a temporary non-erodible dam within the existing stream channel upstream of the work area and install a pump approximately 5m upstream of the dam. The pump will pump flows upstream of the works around the work area and discharge them back into the existing watercourse downstream of the culvert works;

- Sand bags or similar will be used to impound flows for the pump. The inlet of the pump will be supported above the base of the stream and will contain a fish grill, to prevent fish from entering the pump intake structure;
- The pump flow rate will be equal to the expected dry weather flow for the particular stream;
- The Freshwater Ecology Report provides for fish management measures. With the controls in place, any fish observed in any of the pools within the work area will be removed by hand netting and released downstream of the work area. Any fish or eels discovered during excavation will also be captured and released downstream;
- Initial excavation works will remove the vegetation from the work area followed by the excavation of any unsuitable material. This excavated material will be removed from the work area and disposed of within one of the identified spoil sites;
- Once all unsuitable and soft material has been removed from the extent of the culvert to be constructed, the area will be backfilled with the required amount of structural fill and the culvert along with all associated wingwalls, retaining walls and backfill will be constructed;
- Any other construction activity associated with the culvert construction, such as the placement of fill, will only be carried out once ESC measures such as super silt fences, CWDs DWDs, SRPs and DEBs have been put in place. When the works have been completed, any disturbed and exposed areas of bare earth will be fully stabilised through mulching or vegetation establishment;
- Once the necessary ecological approval has been obtained, the pump and bund will be removed and the stream flows can then be passed through the new culvert structure; and
- Where an existing culvert is to be extended, a plywood bulkhead, or equivalent, with a flexible bypass pipe fixed into the bulkhead of the culvert will be installed. The bulkhead will be sealed into the base and sides of the existing culvert. If required a supplementary pump will be used to ensure a dry working environment. The flexible bypass pipe will be a sufficient length to allow low flows to discharge beyond the works area.

(b) All culvert works

The following will be required for the construction of all culverts:

- Prior to any works commencing on the construction of a particular culvert a period forecast of dry weather sufficient to construct the culvert will be confirmed through appropriate weather monitoring system;
- Culverts are expected to be installed in sections and sections will be fully constructed and the immediate area stabilised at the end of each working day;
- Any water present within the work area will be pumped to a DEB which will be located away from, and discharge away from, the stream environment;
- On completion of the culvert extension, all plant, materials and labour will be demobilised and the site will be permanently stabilised in accordance with the CЕСP for that work area; and
- Any rock armouring required for stabilisation purposes at the outlet of the culvert will be placed and accommodated as required.

In the event of high rainfall during the course of construction of the culvert, or prior to leaving the site for more than a 24 hour period, the following will occur:

- That any loose material that could enter a watercourse is to be removed from the flood plain of the stream;
- Any downstream sand bag barriers will be checked and, if required, removed;
- All existing sediment control measures will be inspected and secured and maintained where required should a significant rain event be forecast. The streambed in the location of the culvert will be fully stabilised to ensure no flows overtopping the upstream dams or bunds can create scour issues. It is expected that this will be achieved through geotextile membrane being appropriately trenched in at the head and toe of the work area; and
- Extend the working hours in accordance with any constraints in the Designation Conditions, if it is believed to have significant benefit with regard to programme, forecast weather events and environmental impacts.

To demonstrate that the culvert construction can be undertaken in an effective manner during construction we have developed a conceptual methodology for the construction of Culvert 55300 as set out below.

(c) Culvert 55300 – Conceptual ESCP

Culvert 55300 is located to the North of Spoil Site 10, it is required to transfer the diverted flows via the permanent stream diversion, to the east of the alignment, beneath the proposed road embankment into the Right Branch of the Mahurangi River.

The culvert will be constructed off-line in a 'dry' environment. Activity associated with the construction of this culvert will be the establishment of the permanent stream diversions, the construction of the concrete headwalls, bulk earthworks movements required to construct the road embankment and the deposition of spoil within Spoil Site 10.

The construction sequence of the culvert will be carried out in stages as discussed in Section 6.1.4. This includes the transfer of flows from the catchment upstream of the culvert to the Right Branch of the Mahurangi River with the culvert works being carried out as below:

- Place a sand bag barrier downstream of the culvert to prevent any construction runoff from the work area from flowing along the diversion channel, ground water and surface water flows from within the works will be pumped to a DEB;
- Excavate for the base of the culvert, removing all spoil from the work area and either remove directly from site or deposit within the spoil site;
- Construct the culvert in accordance with the construction drawings including any headwalls, upstream entry works, downstream energy dissipation and permanent erosion protection and fish passage measures;
- Construct a CWD (A2) and the permanent stream diversion (C2) upstream of the culvert location around the perimeter of the spoil site location;

- Construct any permanent erosion protection measures and stabilise the stream diversion channel; and
- Once the permanent stream channel has been confirmed as stabilised from an ESC perspective the CWD can be decommissioned and runoff from the natural catchment upstream of the works can be allowed to enter the permanent stream diversion and channel and flow through the culvert.

The conceptual construction sequence discussed above is a description of only one possible method of construction and we have demonstrated that it can be managed effectively to control erosion and sedimentation.

We consider the above construction methodology is based around the construction works being completed offline in a 'dry' environment. We consider that such provisions can apply to all works of this nature and that this gives confidence that effects from the proposed stream diversion will be minor. As with other works the construction of culverts on the Project will be subject to the development of CESCPS.

6.1.7 Bridges and viaducts

Bridges and viaducts will be required to span across natural gullies, roads, watercourses and at the Okahu Creek/Billings Road location within the Coastal Marine Area (CMA). Bridge and viaduct construction will typically involve piling operations to form a stable foundation onto which precast reinforced concrete columns will be constructed. The conceptual construction sequence is discussed in more detail in the construction section of the AEE.

Pre-cast and Pre-stressed concrete elements required for the construction of the bridges and viaducts will be cast in a precast concrete construction yard and then transported to the particular bridge or viaduct location, where they will be placed in position. Once fixed in position the top slab will be poured in-situ to the required depth.

In some cases construction of the bridge will involve establishing structures with sheet piling on either side of a stream system with no instream works required. The placement of a concrete slab over the stream without diverting the stream will complete the bridge structure. In these occasions ESC will be based around placement of controls below the sheet pile locations but above the stream bank profile.

Any temporary crossing of stream systems as part of a bridge / viaduct construction will be detailed within a CЕСP. These crossings will likely be in a Bailey Bridge form.

To demonstrate that the construction of bridges and viaducts can be carried out with effective environmental management including erosion and sediment control during construction, we have developed a conceptual methodology for the construction of the Okahu Viaduct.

(a) Okahu Creek Viaduct – Conceptual methodology

The Okahu Viaduct is a 524 m long, 8 span concrete box girder viaduct, which crosses the Okahu Creek, within the Pūhoi Sector of the Project. Drawings S-021 and S-022 show the conceptual plan and longitudinal section of the Okahu Viaduct.

The Further North design team anticipates that there will be up to 14 piers to be constructed, onto which the precast concrete box girders will be placed.

Each pier will be constructed on a reinforced concrete pad foundation. Beneath each pad foundation will be 4 reinforced concrete bored piles, which will extend into the ground beneath the pad foundation.

In this scenario, 8 of the piers will be located within coastal Flat of the Okahu Estuary. Construction of pad foundations for 6 of the piers will be below the Mean High Water Springs (MHWS) tide level and environmental measures will be required to prevent tidal ingress into the excavation during construction.

Construction of the remaining 8 piers will be outside of this direct zone of tidal influence. However these pier foundations may be affected by saline /groundwater ingress beneath the MHWS level.

The 6 piers to be constructed below the MHWS level (within the CMA) will occupy an area of approximately 150 m². The area of the temporary access track that will be required within this zone will be approximately 1215 m².

The conceptual construction programme indicates that the construction of the foundations will take approximately 20 weeks and the construction of the reinforced concrete piers will take approximately 40 weeks.

The following conceptual methodology describes the sequence of works and the required measures to be put in place to manage construction of the various elements of the viaduct (Drawings ES-071 and ES-072 indicate the conceptual ESCP for the Okahu Viaduct).

The photographs included below demonstrate where this methodology was successfully used on the NGTR Project.



Figure 13: Photos of Construction method used on Northern Gateway Toll Road project

(i) Establishment of access to pier locations

With reference to Drawings ES-071 and ES-072, construction access can be gained to the Okahu Estuary for the construction of Piers that we have numbered S5, N5, S4, N4, S3, N3, S2, N2, S1 and N1 from Billings Road, north of the structure, where an access track for plant and the delivery of materials will be formed, this will involve access down the coastal bank towards the open channel to the North of the Okahu Estuary. Access for the construction of Piers S7, N7, S6 and N6 will be gained from the south of the structure.

Access to the foundation construction areas will require a crossing of the open channel to the north of the Okahu Estuary. Crossing the low flow channel will require the placement of a bailey bridge. The ecological effects of these works have been addressed in the Marine Ecology Assessment Report.

Works to construct the temporary access track across the coastal flat within the estuary will be carried out during low tide conditions and will be formed as follows:

- Place a geotextile membrane directly onto the coastal flat, on top of which a geogrid material will be placed, on top of which certified clean hard fill will be carefully deposited and compacted to form a stable access track on which construction plant and machinery can track across. The access track will be established in stages across the coastal area as works progress, where work will be completed on the foundations for each set of piers before commencing on the next subsequent set of piers; and
- While the access track consists of a clean hardfill surface, ESC measures required for the construction of the temporary access track across the coastal habitat will be in the form of a DWD which would be formed to receive construction runoff from the access track. The access will be formed to ensure stormwater runoff from the track flows to one side of the track, the DWD would discharge stormwater runoff from the works via a DEB into the estuary.

We note that this is effectively a clean operation and minimal contaminants, including sediment generation should exist.

(ii) Construction of bored piles, pad foundations and piers

From an environmental perspective, the construction of all piers for this structure is similar in nature and therefore the construction sequence and controls required for each pier will be similar.

The construction works for the Okahu Viaduct are expected to be carried out in the following sequence using the access previously established:

- Construct a cofferdam, using sheet piles, vibrated into the ground surface, around the extent of the required excavation. This cofferdam will be required to provide a dry environment for excavation and construction works to take place. It will prevent both tidal ingress during high tide and also prevent 'boiling' of the excavation base due to pore water pressures within the ground beneath the excavation;
- Once the cofferdam is in place, work will begin to remove material from inside of the cofferdam; excavated material will not be stockpiled and will be removed from site immediately and will be transported to one of the identified spoil sites associated with the Project;
- It is expected that any water within the excavation will be pumped to either a CIS or DEB which will be located on the ground above MHWS to the North of the estuary. Pumping operations will continue for the duration of the works required to complete the foundation and bored piles. Once the foundations have been completed, pumping operations will cease and the pump can be removed;
- Once the excavation has reached the required depth, work can commence on the construction of the bored piles. Material removed from the ground during the pile boring works will not be stockpiled within the construction area and will be removed from site immediately and will be transported to one of the identified spoil sites associated with the project. The piles are a concrete structure and any concrete slurry will be managed as defined in Section (b) of this Report;

- Following the completion of the piles, work will commence on the construction of the pad foundation and piers with the placement of steel reinforcement and in-situ concrete being poured;
- Access within the Okahu Estuary will be required up until the bridge beams have been placed and the concrete for the bridge deck has been poured, once these works are completed the access track will be removed by removing the hardfill material and the geotextile from the estuary. The depression in the mud Flat left behind will be allowed to infill naturally during the tidal process. No further access to the coastal Flat is required for this activity and the coastal flat will return to its original profile; and
- The access tracks within the grassed areas to the North and South of the Estuary will be removed and the areas will be stabilised by topsoiling and seeding. Once the grass has become established the DEBs can be removed.

We visited the proposed construction site and consider that from a construction environment perspective, there will be only minor environmental effects. The conceptual construction sequence discussed above is a description of only one possible method of construction, which has been successfully used in other projects and we have assessed that it can be managed effectively to control construction activities as follows:

- Construction runoff from the access tracks required within the grassed areas will be treated using DEBs;
- There will be some minor disturbance, in the form of compaction, to the coastal flat during the construction of the temporary access track across the estuary. The Marine Ecology Assessment Report confirms no issues with this approach;
- The stream to the north of Estuary will be bridged across using a bailey bridge with no instream works;
- Pumped water from the excavation works, will be discharged to, and treated with either a DEB or a CIS;
- Excavated material will not be stockpiled within the estuary or bridge construction zone and will be transported directly to one of the identified spoil sites associated with the Project;
- Once the temporary access track has been removed from the estuary it is expected that the depression left behind in the coastal Flat will quickly re-establish due to natural sediment deposition from tidal action. We note that this is a similar methodology used for the Waiwera Viaduct, constructed as part of the NGTR project, and little or no evidence of the temporary access track is now visible; and
- The principal contractor appointed to undertake the works will be required to produce a CЕСP for various elements of the works including structures where the detailed ESC measures will be set out.

We have assessed that the construction of the Okahu Viaduct is similar in nature to the construction of the Pūhoi Viaduct and Perry Road Viaduct. While these later two viaducts do not involve works within the coastal habitat, we consider that from a construction perspective these structures can also be constructed with minor environmental effects.

We also note that a similar methodology to that described above was used within the NGTR Project for the Waiwera Estuary. This was successfully implemented and provides a further degree of comfort with the proposed methodology.

We recommend that consent conditions be established around development of CESCPS and associated monitoring to ensure that the methodologies are endorsed by Council and achieve the desired environmental outcomes.

(b) Concrete work

Concrete works will be necessary for many of the structures within the Project. During construction of the bridges, it is proposed to minimise the amount of in-situ concrete that will be required through the use of pre-cast elements which will be manufactured offsite and transported to the work area as required.

Any cement contaminated water that does eventuate will require treatment before discharge. This runoff treatment will be achieved by either onsite treatment tanks with the water pH tested before discharge, or the water removed from site through the use of sucker trucks and treated elsewhere.

Concrete placement will be carefully controlled to ensure no loss to the environment through the use of pumps and skips. Concrete truck wash and pump will be provided onsite with a dedicated concrete wash facility, designed to accept such waste.

Onsite treatment tanks will likely take the form of bark filled containers, with the water discharge having to pass through this system prior to discharge. These systems have proven successful in other projects including the New Lynn Rail Trench where pH levels were able to be returned to close to seven with such devices.

We have also investigated the site areas where concrete will likely be used and note that significant vegetative buffers exist in some areas which enable an opportunity to adjust pH levels naturally by discharging runoff over these vegetative buffers by gravity or pumping.

We have considered the use of concrete throughout the Project and assess that the proposed designation provides adequate room to undertake the above works.

(c) Pumping from excavations and shear keys

Pumping operations will be mainly required for the removal of groundwater from excavations such as those required to construct foundations for structures and trenches for pipelines. Dewatering of excavations will be required to allow construction personnel and equipment to undertake construction activities in a dry environment.

(i) Excavations

Where pumping is required from excavations for foundations or trenches it will typically be carried out and managed as follows:

- The pump intake will sit on hard fill material, which will provide a filter media to ensure debris and larger particles are not sucked into the pump intake. The filter media will also act as an

ESC pre-treatment system and will also reduce the risk of direct damage to the internal workings of the pump;

- If the discharge water quality is satisfactory with a minimum 100mm clarity, the pump discharge will be directly to a vegetated environment away from any watercourse;
- Where a suitable vegetated area is not available within the vicinity of the working area the discharge from the pump will be to a DWD and subsequently to a SRP or DEB; and
- If the water clarity of the discharge is not satisfactory, pumping will be to a DEB or SRP and during pumping operations the decant of the DEB or SRP will be manually raised and will remain in that position until sufficient settlement of suspended solids within the discharged water has occurred.

(ii) Shear keys

A shear key is a geotechnical design feature that will be constructed in areas where the existing ground beneath the indicative alignment requires improvement and strengthening to ensure the long-term stability of the road embankment. In addition, due to geotechnical constraints, some shear key establishment may be required as part of the SRP establishment.

There are a number of Shear Keys required along the Project and these are discussed in the Geotechnical Engineering Appraisal Report.

The works required to construct shear keys will typically be:

- The excavation of material to a depth to be determined by a specific geotechnical design;
- The placement and compaction of durable rock fill within the excavation to form the shear key;
- Pumping operations will be required to remove groundwater and any surface water ingress into the excavation; and
- Excavated material from the shear key excavation will likely be classed as unsuitable material and will not be used as structural fill within earth embankments and will be removed from the work area to one of the identified spoil sites within the Project.

The depth required (in some cases in excess of 10m) to construct a shear key will require the pumping operations to be managed carefully and will be carried out in stages as the excavation progresses. From an ESC perspective the pumping of groundwater and surface water ingress from shear keys will typically be carried out in the same way as described above.

Discharges from the pump will be directed to a SRP, or DEB. During the pumping operation, the decants within the SRP or DEB will be manually raised and will remain in that position until sufficient settlement of suspended solids within the discharged water has occurred.

If required, manual batch dosing of the SRP and DEB with chemical flocculant will be carried out to increase the level of sediment retention in the SRP or DEB. Once pumping operations have been completed and the sediment sufficiently settled out, the decants can be lowered and normal operation can resume.



Figure 14: Shear key construction

(iii) Spoil Site (SL10) Shear key – ESCP

For context purposes and to illustrate the concepts involved, we note that there are 3 shear keys proposed through Spoil Site 10 and these are indicated on Drawing ES-094. A typical detail of a Shear Key can be found on Drawing R-217.

In the case of the shear keys for Spoil Site 10 the sequence of works and ESC measures required will be as that described in Section 6.1.4 of this Report.

The specific ESC measures proposed for the shear keys at Spoil Site 10 are shown on Drawings ES-091 to ES-095.

In summary, we consider that the pumping methodologies described above in relation to the dewatering of excavations for foundations of structures, shear keys and trenches for pipework can be achieved using pumps.

This demonstrates that with implementation of appropriate ESC measures and management practices, including the development of CESCOs prior to construction activity taking place, that erosion and sedimentation issues resulting from excavation and backfilling operations can be managed effectively to control the effects of erosion and sedimentation.

6.1.8 Chemical treatment of SRPs and DEBs (flocculation)

Flocculation is a method of increasing the retention of suspended solids from construction runoff. Chemical flocculant is added to the inflows of a SRP or DEB via a rainfall activated system or by manual batch dosing.

The flocculant is a chemical additive which works by neutralising the negative charge of soil particles, thereby accelerating coagulation and increasing the rate of settlement of soil particles and therefore the use of flocculation chemicals increases the efficiency of SRPs and DEBs and reduces the amount of sediment discharged to the receiving environment.

We carried out flocculation trials as part of our assessment, to determine that the addition of flocculant will assist with the settlement of sediment on the particular soils that will be encountered on the Project and to also determine the most appropriate range of products that can be used to increase the efficiency of sediment retention on the Project. Two independent companies undertook the chemical testing on soils that we considered represented those that will be encountered on the Project. The results of these are fully outlined within the WAFR 2.

Table 16 below summarises the 'unassisted' settling of the soils tested (without any addition of chemicals). This table shows that there is some natural settlement of the soil samples. However, we consider the natural rate and extent of settlement to be inadequate and requires chemical assistance in some circumstances to achieve satisfactory soil settlement.

Table 16: Unassisted settling results in nephelometric turbidity units (NTU).

Time	Sample BH 112 soil (NTU)	Sample BH 112 silt stone/rock (NTU)	Sample BH 207 (NTU)
Start	>1000	>1000	>1000
1 hour	58.5	128	>1000
2 hours	24.5	75.8	>1000
5 hours		52.8	>1000
24 hours (1 day)		39.2	545
48 hours (2 days)			240
72 hours (3 days)			158
96 hours (4 days)			121
192 hours (8 days)			106

Following the Unassisted Settling Tests, we also undertook settlement tests using a range of chemical flocculants that could be used on this Project.

The samples tested with chemical flocculants achieved turbidity levels of less than 10 Nephelometric Turbidity Units (NTU) within very short time periods and we agree with the conclusions reached, as defined in the WAFR 2, that in an actual SRP we would expect this outcome to be indicative of the worst case scenario.

In established SRPs and DEBs onsite there is likely to be a considerably greater settling time. When considered within the field context and with conditions such as wind action across the pond, the laboratory results are assessed as being indicative of the actual sediment settling expected in practice. The results of the flocculation trials are shown below in Figure 15.

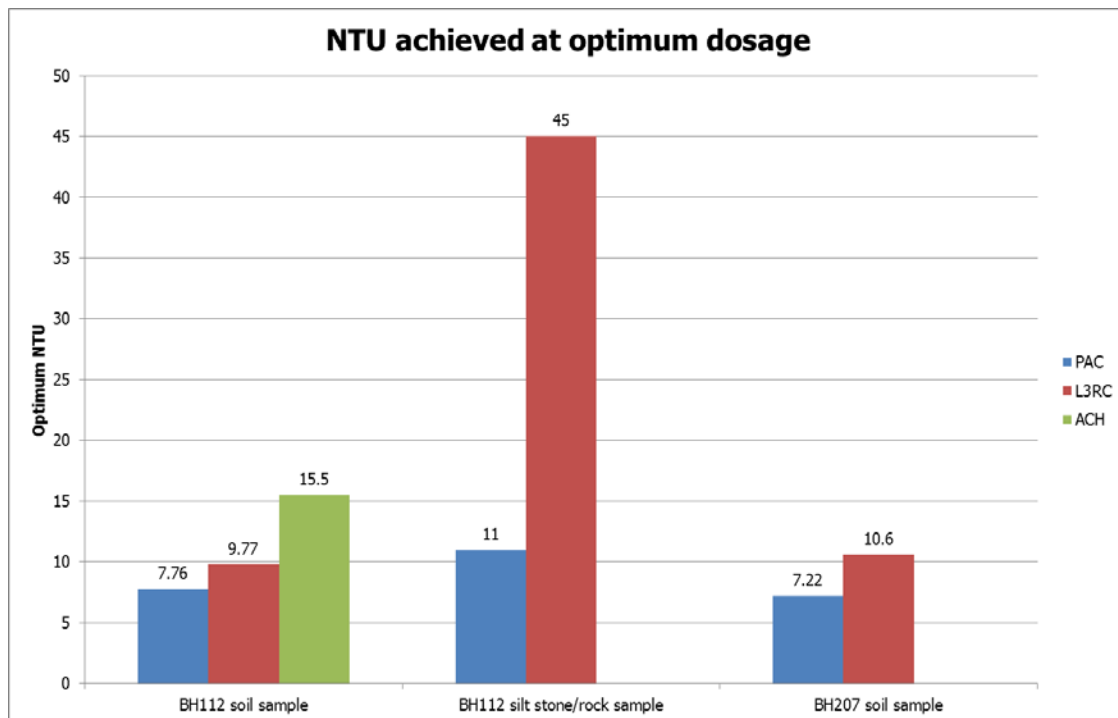


Figure 15: Soil settlement after chemical treatment (NTU) (10 minute duration)

We note that our experience with other projects, such as Long Bay in Auckland show that increased sediment retention efficiencies can be achieved using chemical flocculants.

The Long Bay project and also the earlier NGTR Project both used flocculants as an aid to increasing sediment retention within SRPs. At Long Bay in particular, flocculants are used in both SRPs and DEBs in both rainfall activated and batch dosing regimes. Batch dosing refers to the manual application of the flocculant to the detention device.

On the Long Bay project, selected SRPs are currently continuously monitored during earthworks for Total Suspended Solids (TSS) and pH levels, and a management programme is put in place where if the rainfall activated dosing systems do not achieve a visual clarity of 100mm in the detention structure then batch dosing immediately occurs until this level of clarity is achieved.

Flocculation is a key structural management tool and with appropriately trained personnel managing and using this measure, it has proven to be a critical feature of successful ESC.

We further note the successful use of poly aluminium chloride as a specific flocculant has been endorsed fully by Auckland Council in their Technical Publication 227 (TP 227) and has achieved excellent water quality results throughout the majority of recent earthworks projects in the Auckland Region, with no reported residual effects.

Our chemical tests have proven two key elements:

- That there are chemical flocculants readily available on the market that are proven to be successful and will achieve the required flocculation of the suspended sediments from the soil types that will be encountered within the Project; and
- That the level of treatment necessary, based on the tests, is very minimal with low dosage rates required as illustrated through the WAFR 2.

We therefore assess that chemical treatment of SRPs and DEBs will be a key ESC management tool on the Project. The design, establishment, operation, maintenance and monitoring of chemical dosing systems will be based on the tests as provided within WAFR 2, however these chemical treatment measures will be specifically determined through the CЕСSCP process.

Furthermore, the proposed adaptive monitoring programme, as discussed in Section 8 of this Report, will include continuous monitoring to ensure that appropriate water quality is being achieved from the discharge of construction runoff and also that any residual effects are minor only.

6.1.9 Riprap placement

Riprap material is a permanent erosion protection measure and is most commonly used along stream banks and at culvert outlets. Riprap resists the erosive action of water flowing across the surface of a stream bank, which can lead to erosion or failure and collapse of the bank. Riprap will be used on the Project in a number of locations as permanent erosion protection measures.

This will typically be associated with the inlet and outlets of culverts, and also be used for stabilisation in stream diversions. From a temporary perspective riprap will be used to provide erosion protection at the outlet of the SRPs.

While placement of riprap is a relatively simple process, we outline below the methodology that will be used for the placement of a riprap within an existing stream environment and also discuss the ESC measures required.

A conceptual construction sequence for riprap placement in a stream channel is described below:

- A clear weather window will be established prior to commencing works on the riprap placement. Clearance of the stream bank can commence and will only be carried out to allow sufficient room for the riprap to be placed;
- A temporary flow diversion will be established to keep water away from the works during the placement of the riprap. The bank slope will be cleared of bushes, trees, stumps or other organic material, loose and soft material will be removed from the bank and a smooth, uniform surface formed;
- A separation layer of geotextile and a filter layer of stone will be placed and spread evenly across the extent of the riprap location, using an excavator; and
- The riprap material will be free of any silt, clay or organic material such as silt and will be carefully placed to the required depth. Larger rocks will be placed at the toe of the riprap and will be evenly distributed across its width.

The placement and use of riprap on the Project will be placed generally as detailed in this Report. Accordingly, they will not create any environmental effects.

6.1.10 Stormwater wetland establishment

A construction issue that is relevant to the operational water management is the timing of the switch from construction to operational water treatment devices. This is a practical issue when an operational stormwater treatment device is located at the same location as the construction water management device e.g. sediment retention pond for construction stage modified to a wetland for the long-term operational phase.

In these circumstances the same earthworks footprint will apply and the sediment retention device will simply be constructed as per normal construction techniques but with the outlet device incorporating the same outlet structure device as the permanent structure. It will continue to operate as a construction related device and once the criteria for operational implementation is met then the outlet will be changed to reflect operational requirements. Flocculation will be reconsidered and may no longer be necessary at this stage.

From our experience in other development projects, we recommend that the operational water treatment devices will generally need to progress from the construction water management device when 80% of the catchment is in its permanent form e.g. stabilised by vegetation and roads sealed.

6.1.11 Access track and haul road establishment

Access tracks and haul roads will be required on the Project to transport, plant machinery, personnel, materials, earth and fill material throughout and between construction zones on the project.

If required to provide an all-weather access, access tracks and haul roads will be constructed using rock taken from rock cuttings within the Project, or imported material. The material will be temporarily stockpiled and once sufficient material is available it will be used in the construction and formation of the access track and haul roads. A typical detail of an access track can be seen in Figure 16 below.

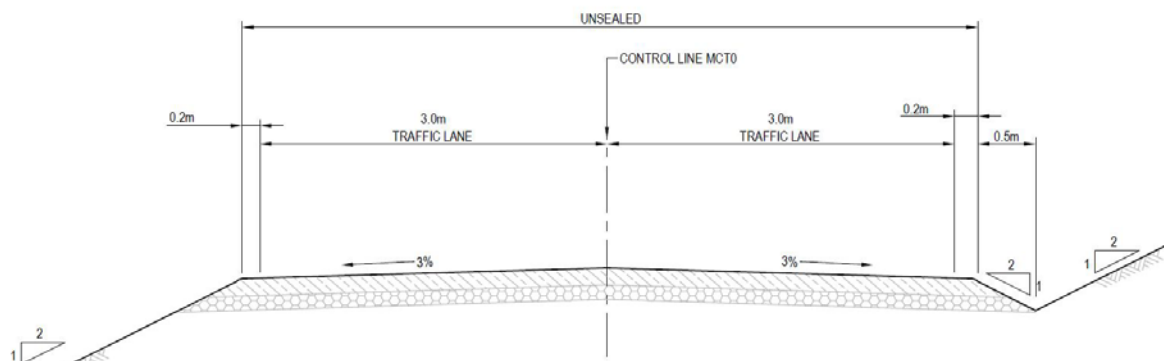


Figure 16: Access track and haul road typical detail

DWDs will be constructed on each side of the access track and haul road to receive runoff. These DWDs will discharge to the receiving environment via a DEB, or SRP. During the construction period water carts will be used to spray the access tracks and haul road with a fine spray to wet the surfaces to suppress dust. We consider these haul roads are relatively simple to manage and can be treated as isolated areas of works with the associated ESCs in place.

Where haul roads form a component of the larger earthworks footprint the control measures will likely be incorporated into the wider site erosion and sediment control measures and the relevant CESCOs. Figure 17 and Figure 18 below illustrate the use and establishment of a construction haul roads.



Figure 17: Earth moving plant trafficking a haul road



Figure 18: Water cart dust suppression

6.1.12 Construction yards and staging areas

Construction yards along the Project will be required for repairs, maintenance, re-fuelling of earthmoving equipment, lay down and storage areas for materials delivery, workshops, project offices, messing, and ablution facilities. They will operate throughout the construction period. The construction section of the AEE includes the details of the yards and the expected use.

Table 17 below, outlines the expected locations of the yard areas as detailed within Section 6 of the AEE.

Table 17: Construction yard areas

Access	Construction zone
Bridge Staging Area-1	Okahu Creek Viaduct North Abutment
Construction Yard-2	Zone-1 and Zone-3
Project and Design Office Area-2	Zone-4 and Zone-5
Bridge Staging Area-3	Pūhoi River Viaduct South Abutment
Construction Yard-4	Zone-5 South
Construction Yard-5	Zone-5 North
Bridge Staging Area-6A and 6B	Hikauae and Schedewys Hill Viaducts North Abutments
Construction Yard-7	Zone-7A
Construction Yard-8	Zone-7A and Zone-7B
Construction Yard-9	Zone-7B and Zone-8
Construction Yard-9a	Kauri Eco Viaduct South Abutment
Bridge Staging Area-10	Perry Road Viaduct South Abutment
Construction Yard-11	Zone-9C South
Construction Yard-12	Zone-9 North
Bridge Staging Area-13	Woodcocks Road Viaduct South Abutment
Construction Yard-14	Zone-11
Precast Yard Area-15	Zone-10

Bridge staging areas are included within the above for the assembly of launching gantries, lay down and storage areas for materials delivery, workshops, project offices and tool-box, messing and ablution facilities.

6.1.13 Construction yards water management measures

ESC devices to be used for the establishment and operation of construction yards will be as follows:

- Stabilised Construction Entrances will be established as the entry point to the proposed construction yard to reduce transfer of sediment onto the external road network;
- If necessary CWDs will be established at the perimeter of the site to intercept and divert offsite water and overland flow from the catchment uphill of the construction yard from entering the areas;
- DWDs will be constructed to intercept and divert runoff from the surface of the earthwork areas within the work area and will discharge it to a SRP to assist with removal of sediment from the runoff prior to discharging to the receiving environment;
- Super Silt fencing – These will be placed during the yard establishment phase of works if necessary;
- The construction yard establishment is recognised as a quick process whereby earthworks activity to establish the platform is completed as a single operation. The topsoil stripping and any subsoil stockpiles will be managed as per Section 6.1.3 of this Report and will be stabilised (likely with a mulch cover) immediately on establishment;
- Immediately on reaching grade the yard area will be stabilised with a 50 to 100mm thick layer of clean hard fill material. This has the purpose of achieving immediate stabilisation but also ensuring traffic movement to and from the site will not be a generator of any further sediment yields;
- The SRP will remain after the yard is stabilised and will act as an attenuation device for the short term operational aspect of the yard. This SRP will be sized as detailed within WAFR 1 and equates to approximately 500m³ of storage volume per 1ha of contributing catchment area. This will provide for treatment during the earthworks activity while also providing water quality treatment and extended detention treatment for the impervious areas associated with operational aspects of the construction yard;
- In accordance with the NZTA Draft Standard the decant structure from the SRP will remain through the entire duration of the construction yard life with the decant design providing the required extended detention flow rates. Calculations to support this are provided within the WAFR 1;
- The SRP will remain in place until the yard is no longer required and is returned to a vegetated or final land-use state; and
- Drawing ES-081 provides a conceptual yard water management plan that will be implemented during the yard development process.

Further water management practices to be used in the operation of the construction yards during construction will be as follows:

- Vehicle movements and parking will only be within designated areas of hardstanding;
- Non-Sediment Contaminants (Chemicals, petroleum and solvent based) products are to be stored within appropriately designed bunded areas;

- Regular clearing of sealed hardstanding areas will be carried out using a road sweeper to remove deposited material from the surface that could become mobilised during rain events;
- All material stockpiles located within the yard confines will ensure treatment through the SRP; and
- Sediment will be removed from the SRP's associated with the individual construction yards when accumulated sediment exceeds 20% of the available storage volume for the particular device.

Some of the construction yards will be utilised as an Industrial Trade Process (as defined within the ARP:ALW). These will be managed as above and will include treatment and management measures as outlined in Section 6.1.7(b) of this Report.

The specific detail of these yards will be highlighted within the CESCPS to be submitted prior to construction commencing. We recommend conditions of consent that will ensure that the above methodologies and processes are undertaken such that effects from each construction yard development are minor.

6.1.14 Monoslope development

There will be a number of monoslope cuttings on the Project. The monoslopes include formation in Pakiri sandstone material. During the bulk earthworks activity for these slopes various ESC measures will apply such as SRPs, DEBs and sediment sumps at the base of the excavations.

Progressive stabilisation and the early establishment of permanent planting will occur as construction progresses; this will reduce the erosion of the softer silts and clay layers overlying the Pakiri sandstone formation and will reduce the subsequent transfer of sediment to the receiving environment.

Vegetation establishment for the sandstone material is however more difficult to achieve due to the steep slopes and the inherently limited water holding capacity and infertility of the sandstone material.

Experiences of the operational phase of the NGTR relayed to the Further North ESC team by Mr. Peter Mitchell of the Auckland Motorway Alliance have illustrated that the rock faces on the NGTR have continued to erode during the operational phase of that project and have led to an increase in the level of maintenance required to remove accumulated sediment from the toe drains and the permanent stormwater treatment ponds. The experience is that while sediment results from these areas, the yields are not at the same level as from weathered soil material and can be relatively easily captured.

It is recognised that stabilisation of the monoslope locations is difficult and that the exposed rock face will lead to some sedimentation during the operational phase of the Project. To reduce the effect of sediment reaching the receiving environment, we propose that permanent stormwater treatment ponds or wetlands be constructed immediately downstream of the monoslopes and that these form part of the operational stormwater treatment process.

As the sediment from the monoslope cut faces will be treated using stormwater wetland or ponds during the operational phase of the Project, and the various ESC measures discussed above during

construction, these areas have been disregarded when we determine the limit on the open area of earthworks during the construction phase.

To assist with achieving a stabilised surface we also recommend that stabilisation trials be established early in the Project phase to determine stabilisation options for these monoslope locations.

6.2 ESC focus areas and approach

As part of the ESC assessment detailed in this Report, we have determined that the geology, soil types, climate, topography and slope classes are consistent between various parts of the Project. Therefore we have not developed detailed sector specific ESCPs for the whole of the Project alignment.

The Further North ESC team, in conjunction with the wider environmental team of experts, determined that assessing the effect of sediment generation from the two specific ESC Focus Areas, and then extrapolating the results of that assessment across the remainder of the Project, is an appropriate way of assessing the environmental effects of sediment yield into the receiving freshwater and marine environments for the Project as a whole.

Accordingly, we have selected the Perry Road and Moirs Hill Road Sectors as the two ESC Focus Areas and we have developed conceptual construction methodologies for these sectors. These determine the nature and feasibility of the specific ESC measures and the expected sediment yield from the construction activity proposed in those sectors. The specific ESCPs for these Focus Areas are briefly summarised below.

Based on the ESCPs developed for the Focus Areas, we expect that there will be a correlation of the sediment yield results and hence a consistent approach to the establishment, operation and maintenance of ESC measures and practices will be applied to the remaining parts of the Project.

We have visited the majority of the project route and have checked the practicality of the ESCPs within the Focus Areas and the ability to extrapolate the concepts over the rest of the Project. This conclusion is further supported by the fact that the Hill Focus Area represents a difficult component of the works, and if ESC measures can achieve the desired outcomes in this location they can be achieved elsewhere on the balance of the Project.

During the assessment process the subject of this Report, the nature of the conceptual construction programme for the Project has changed due to ongoing design refinements. Therefore there is a difference between the conceptual construction programme used for the Focus Area assessment and the final conceptual construction programme presented within the construction section of the AEE. However, we have assessed these changes to be immaterial from a sediment yield perspective as the same geology and slope characteristics and therefore the same construction related issues and conceptual approaches apply.

Consequently the ESC measures and practices discussed above, are conceptual but provide sufficient information and confidence to illustrate that the sediment yields arising from the construction works can be managed effectively.

Accordingly, from an ESC perspective, we would expect that:

- The Flat Focus Area will represent the Perry Road and Carran Road Sectors of the Project; and
- The Hill Focus Area will represent Moirs Hill North, Schedewys Hill, Pūhoi and Hungry Creek Sectors of the Project.

The following ESCPs have been developed with reference to the conceptual construction staging developed for the Project and are based on a 5-year construction period. These ESCPs are themselves conceptual in nature and we have prepared them to demonstrate that sediment generated by the construction of the Project can be effectively managed.

6.2.1 Flat Focus Area – Perry Road Sector - Woodcocks Road Overpass to Perry Road Viaduct (CH49250 to CH53100) – Construction Zone 9

The Flat Focus Area is approximately 3.76km long and is located within the Perry Road Sector of the Project. It runs from the southern abutment of the Woodcocks Road Overpass (CH49,250) to the northern abutment of the Perry Road Viaduct (CH53,150).

This Focus Area is largely representative of the terrain that extends across the Kaipara Flat (encompassing the Perry Road and Carran Road Sectors of the Project).

(a) Flat Focus Area – Existing environment

The existing features within this Focus Area are as follows:

- **Geology and Hydrogeology**
 - The geology of this sector generally comprises Pakiri Formation in the south and isolated elevated Pakiri Formation hills separated by wide flat valley floors of alluvial deposits surrounding Warkworth Township. Pockets of Mahurangi Limestone (Northland Allochthon material) are encountered to the north of Woodcocks Road. Further information of the Geology and Hydrogeology for this Sector can be found within the Geotechnical Engineering Appraisal Report and the Hydrogeology Assessment Report.
- **Hydrology**
 - Section 3 of this Report provides an overview of the rainfall data for the Project and demonstrates that there is spatial distribution of rainfall along the route. However, from an ESC perspective this variation is not considered significant and the rainfall can be considered consistent throughout the Project.
- **Existing Streams and Watercourses**
 - These are discussed in Section 3 of this Report and for the Hills Focus Area all streams and watercourses discharge into the Mahurangi River.
- **Existing land-use**
 - The existing land-use in the Perry Road Sector of the Project is predominantly Pastoral farming with extensive tracts of pasture for mixed grazing.

(b) Flat Focus Area – Construction activity

The ESCP for this Focus Area has been developed with reference to Section 6 of the AEE, and consequently the ESC measures proposed below take into account the various us construction activities discussed in that Report. A copy of the conceptual ESCP developed during the preparation of this Report is shown on Drawings ES-020 to ES-023.

The major construction to be carried out in the Perry Road Sector is as follows:

- The construction of the Wyllie Road Overpass;
- The construction of eight culverts;
- The excavation of approximately 1.71M m³ of soil, rock and unsuitable material;
- The placement of approximately 1.09M m³ of excavated soil and rock material in fill embankments; and
- The deposition of approximately 0.62M m³ of unsuitable material in spoil sites or the extension of landscape bunds within the proposed Project designation.

The construction for this Focus Area will require approximately 35.7 ha of land to be earthworked. The maximum area of open exposed land at any one time, within this Focus Area, will be approximately 27 ha.

Figure 19 indicates the extent of the open area over time during a five year construction programme for the Flat Focus Area.

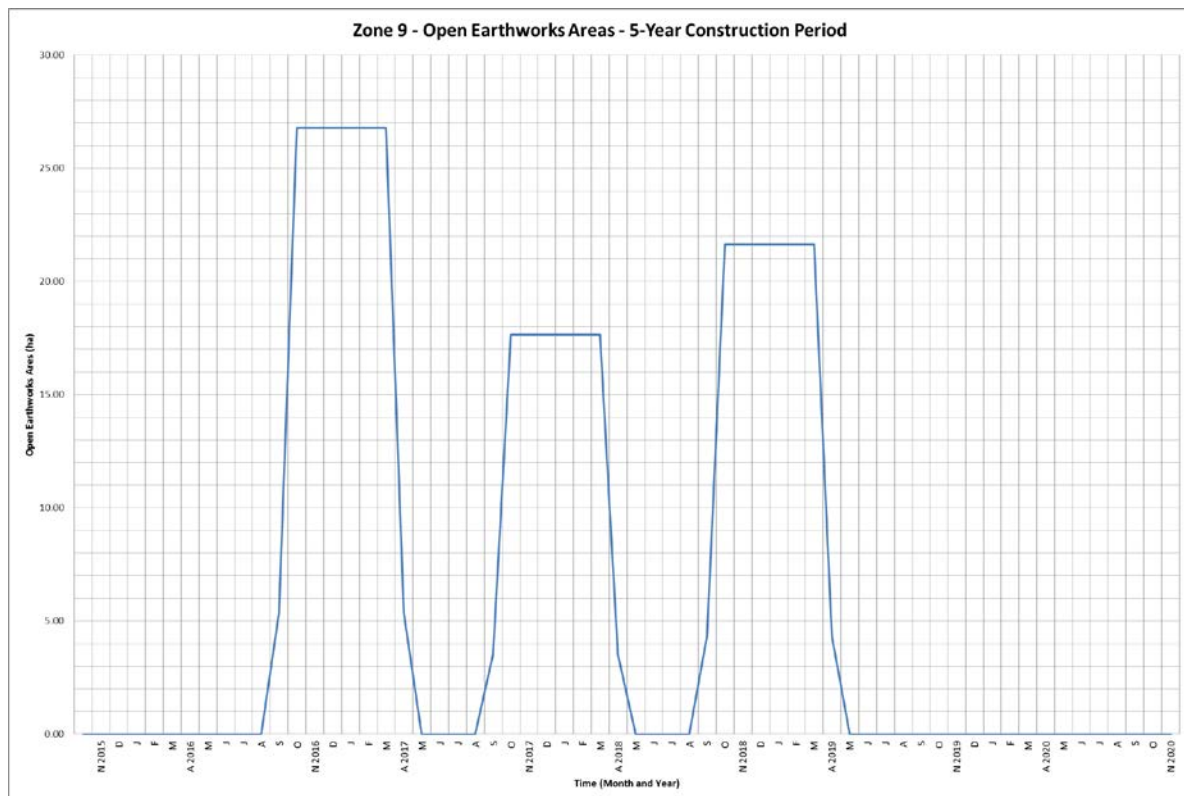


Figure 19: Focus Area (Zone 9) – Modelled extent of open areas based on the construction programme

Whilst the construction methodology has been developed and highlights a number of discrete activities to be carried out during construction, it is recognised that a number of these activities are linked and are dependent on one another. Following the development of the conceptual ESCPs for the Flat Focus Area we have demonstrated that through the implementation of a range of structural and non-structural ESC measures and practices, including the implementation of SRPs, DEB, CWDs, DWDs and chemical treatment, that erosion and subsequent sedimentation can be managed effectively throughout construction.

We assess that the development of a conceptual ESCP can be achieved. Our assessment also confirms the ability to establish a similar ESCP for the flatter parts of the Project, which include the Perry Road and Carran Road Sectors of the Project.

We visited the Focus Area site and walked the route from Woodcocks Road to the site of the proposed Perry Road Viaduct and consider that the conceptual methodology is appropriate and can be further developed prior to construction. We therefore assess that the conceptual ESC methodology can be reliably used in the sediment modelling exercise. With the implementation of site specific CESCPS, which will include a range of structural and non-structural ESCs, we assess that there will be minor environmental effects only.

The conceptual ESC methodology developed is detailed in Drawings ES-020 to ES-023 and is based on the principles as outlined in Section 5 of this Report.

6.2.2 Hill Focus Area - Moirs Hill Road Sector - Moirs Hill Road to Perry Road Viaduct (CH53450 to CH56800) – Zone 7B

The Hill Focus Area is approximately 3.75km long and is located within the Moirs Hill North Sector of the Project. It runs from the southern abutment of the Perry Road Viaduct (CH 53,450) to the Moirs Hill Underpass (CH 56,850).

This Focus Area is representative of the terrain likely to be encountered in the Schedewys Hill, Hungry Creek, and Pūhoi Sectors of the Project and therefore the ESC measures and practices detailed for this Focus Area can be equally applied to those Sectors, but will be subject to the development of detailed CESCPS prior to construction commencing.

(a) Hill Focus Area – Existing environment

The existing features within this Focus Area are as follows:

- **Geology and Hydrogeology**
 - The geology of this sector is shown on Figure 7 and predominantly comprises Pakiri Formation. Further information of the Geology and Hydrogeology for this Sector can be found within the Geotechnical Engineering Appraisal Report and the Hydrogeology Assessment Report.
- **Hydrology**
 - Section 3 of this Report provides an overview of the rainfall data for the Project and demonstrates that there is spatial distribution of rainfall along the route. However, from an ESC perspective this variation is not considered significant and the rainfall can be considered consistent throughout the Project.
- **Existing Streams and Watercourses**
 - These are discussed in Section 3 of this Report and for the Hills Focus Area all streams and watercourses discharge into the Mahurangi River.
- **Existing land-use**
 - The existing land-use within the Moirs Hill Sector is predominantly large established forestry plantations. The main areas of forestry include the extensive areas associated with Moirs Hill near Pohuehue Reserve. These forests are largely comprised of mixed aged stands of pine and extensive clear felled areas particularly to the north.

(b) Hill Focus Area – Construction activity

The ESCP for this Focus Area has been developed with reference to Section 6 of the AEE, and consequently the ESC measures proposed below take into account the various construction activities discussed in that Report. The conceptual ESCP we have developed is shown on Drawings ES-018 to ES-020.

The major construction to be carried out in the Moirs Hill Road Sector is as follows:

- The construction of six culverts;

- The excavation of approximately 3.61M m³ of soil, rock and unsuitable material;
- The placement of approximately 2.41M m³ of excavated soil and rock material in fill embankments; and
- The deposition of approximately 1.2M m³ of unsuitable material in spoil sites and in the extension of landscape bunds within the proposed Project designation.

The construction for this Focus Area will require approximately 54.2 ha of land within the Focus Area to be earthworked. The maximum area of open exposed land at any one time, within this Focus Area, will be approximately 43 ha derived from the constructability assessment. Figure 20 indicates the extent of the open area over time during a five year construction programme of the Hill Focus Area.

The conceptual construction programme for this Focus Area includes a period of winter working, where bulk earthworks operations will be carried out on the harder siltstone material that will be exposed within a number of cuttings.

Based on particle size distributions, site observations and our analysis, we assess that sediment yields from the rock cut face will be considerably less than that of the cuts through the spoil layers above. ESCs will be in place, such as chemically treated SRPs and DEB's along with appropriate site management, such as progressive stabilisation and construction staging.

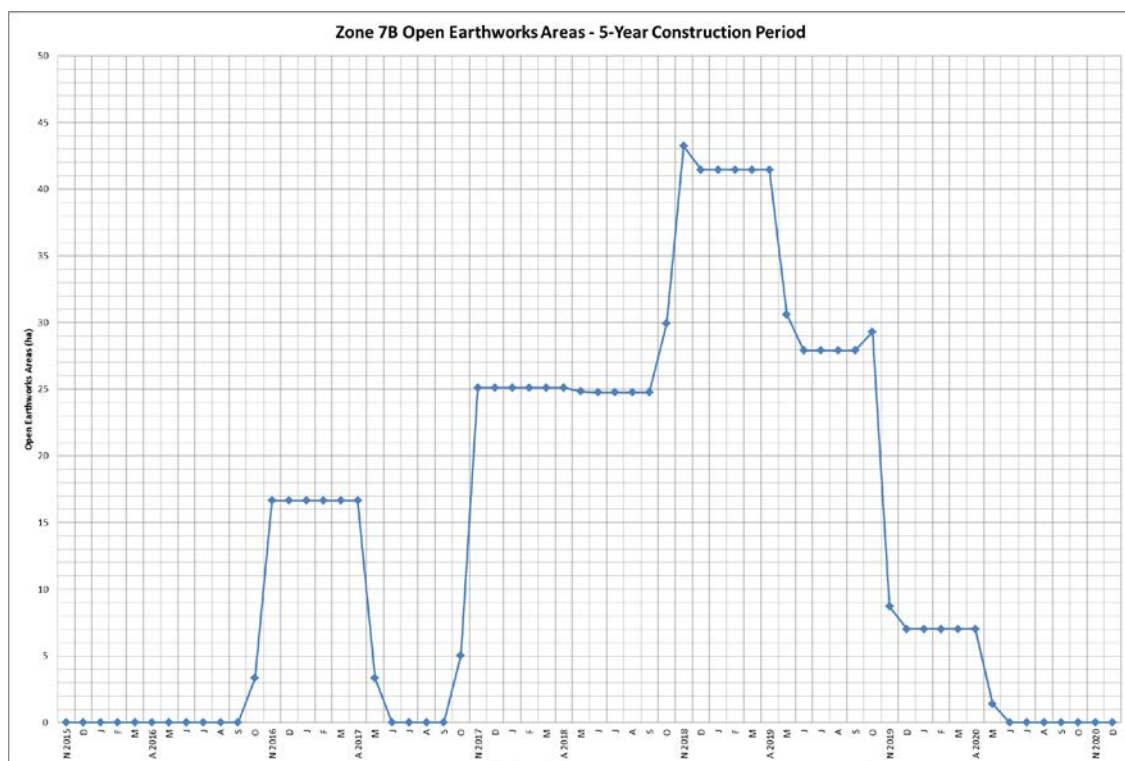


Figure 20: Focus Area (Zone 7B) – Modelled extent of open areas based on the construction programme

Following the development of the conceptual ESCPs for the Hills Focus Area we have demonstrated that through the implementation of a range of structural and non-structural ESC measures and

practices, including the implementation of SRPs, DEB, CWDs, DWDs and chemical treatment that erosion and subsequent sedimentation can be managed effectively throughout construction.

We assess that the development of a conceptual ESCP in this location confirms the ability to establish a similar ESCP for the remaining Hill parts of the Project which includes the Moirs Hill North, Schedewys Hill, Hungry Creek and Pūhoi Sectors of the Project.

We have visited the Focus Area and walked components of the route from the site of the proposed Perry Road Viaduct to Moirs Hill Road and consider that the conceptual methodology is appropriate and can be further developed prior to construction. We therefore assess that the conceptual ESC methodology can be reliably used in the sediment modelling exercise. With the implementation of site specific CESCOs, which will include a range of structural and non-structural ESCs, we assess that there will be minor environmental effects only.

The conceptual ESC methodology developed is detailed in Drawings ES-018 to ES-020 and is based on the principles as outlined in Section 5 of this Report.

7. Sediment modelling and interpretation

Sediment modelling

GLEAMS modelling has been carried out to assess sediment yields from proposed earthworks activity and to determine the background sediment yields from the existing land-use within the proposed earthworks footprint.

To provide a comparative analysis to the GLEAMS results, USLE calculations have also been undertaken to determine the construction sediment yields. There is a good correlation between the GLEAMS and USLE results.

The mean annual sediment yields for the 5 year and 10 year construction programme scenarios have been calculated for the two Focus Areas. We have averaged the sediment yields between the 5 and the 10 year construction periods and consider that for the Hill areas a sediment yield of 49.1 t/ha/year is representative. For the Flat areas a sediment yield of 22.9 t/ha/year is representative. These sediment yields include the background load and stabilised area sediment yields during the construction period.

The sediment yield calculations undertaken provide an estimated annual average sediment yield from the Project and suspended sediment concentration that may occur in a 2 year, 10 year and 50 year storm events. The sediment yield (including suspended sediment concentration), is then applied to the receiving environment to assist with the assessment of effects during the construction period. This overall assessment includes an assessment of the earthworks open area that will be applied to the Project.

Environmental risks

Key erosion control risks are identified as those works within, and adjacent to, watercourses, steep slopes and spoil site establishment. The slope of the existing topography is a key factor in the calculation of sediment yields. With a 50% reduction in the existing slope angle, which is considered realistic for many of the proposed earthworks operations onsite, we can expect that there will be a corresponding 67% reduction in sediment yield.

Through the results of the sediment modelling, other key risks are identified which relate to those areas of higher sediment yield, typically within the Hill country. These higher risk areas will be a point of focus and will attract a higher degree of attention with rainfall monitoring and forecasting, structural controls and a range of non-structural control measures being implemented.

Nutrient modelling has also been undertaken which confirms that on a Mahurangi Catchment-wide basis we assess that the Project will increase the total load of phosphorus by 7% and nitrogen by 8%. We expect this sediment-N and sediment-P to be released in pulses with sediment during rainfall events.

7.1 Rainfall probability

Whilst high return period rainfall events occur relatively infrequently, when a construction project extends over several years the probability of a high return period event occurring increases.

For example, the probability of a 100 year Annual Recurrence Interval (ARI) rainfall event occurring in any given year is 1%. However, the probability of its occurrence increases by 1% per year (i.e. in the last year of a 5 year construction programme the probability of a 100 year rainfall event occurring is 5%). Figure 21 shows the probability of a rain event being equalled or exceeded in a range of construction periods from one to ten years. The graph is based on the probability formula:

$$P_T = 1 - (1 - P_f)^n$$

Where:

- P_T is the probability of occurrence for the entire period, in this case ten years
- P_f is the probability of occurrence for in any single year
- n is the total time period in years

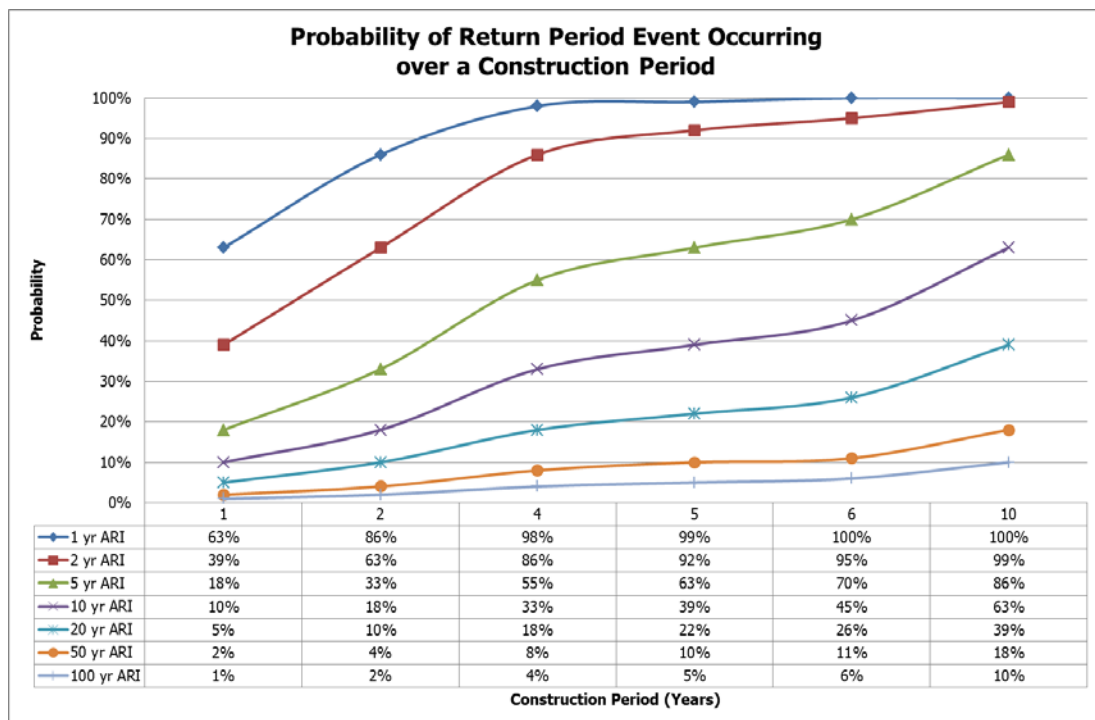


Figure 21: Rainfall probability graph

From a risk perspective it can be seen that during a 5 year construction period there is a 99% probability of a 1 year ARI rainfall event occurring and a 63% probability of a 5 year ARI rainfall event occurring. For the 50 year and 100 year ARI rainfall events the probability of occurrence is 10% and 5% respectively.

For a 10 year construction period the probability of occurrence increases for all rainfall event return periods. During the development of our assessment we considered the rainfall event probabilities for a 5 and 10 year conceptual construction programme, which includes periods of time for enabling and decommissioning operations to be carried out.

These scenarios therefore include slightly shorter overall earthworks periods. It is also noted that the construction section of the AEE includes a conceptual 5 year construction programme and does not include any limits on the extent of open areas of earthworks for the construction of the Project.

Overall, the rainfall analysis has demonstrated that should the construction period extend beyond the 5 year conceptual construction programme, then the probability of a higher return period rainfall event occurring also increases.

It is important to note that the 'maximum open earthworks period' for each year will not take place during a full calendar year but only during the traditionally drier summer periods (October to April) and as such the probability of a high return period rainfall event occurring (such as a 50 year ARI event) reduces when considering this reduced earthworks season. .

7.1.1 Historic rainfall data

An assessment of recorded rainfall taken from rain gauges in the vicinity of the Project supports the rainfall probability and risk concept discussed above. We have included a summary of rainfall records we have obtained, based on frequency analysis using hydrological statistical methods, from Mahurangi and Warkworth rain gauges, in Table 18.

Table 18: Summary of historic rainfall data

ARI (years)	Number of recorded events		
	Mahurangi		Warkworth
	6 Hour Duration	24 Hour Duration	24 Hour Duration
2	10	6	33
5	3	3	14
10	0	2	8
20	2	0	1
50	0	0	1
100	0	0	1
Total number of events exceeding the 2 year event	15	11	58
Record time period (years)	18	18	90

The Warkworth data set extends for a period of 90 years and shows that 58 recorded events exceeded the 2 year 24 hour duration rainfall event, eight of which were 10 year 24 hour rainfall events and one each for the 20, 50 and 100 year 24 hour rainfall events.

We also analysed an 18 year rainfall record, from the Mahurangi raingauge, which showed that 15 recorded events exceeded the 2 year 6 hour duration rainfall event, and 11 recorded events exceeded the 2 year 24 hour rainfall event. Two of these events were 20 year 6 hour duration rainfall events and two were the 10 year 24 hour rainfall events. No events were recorded for the 50 year or 100 year ARI rainfall events during the 18 year record.

The ARI describes the average annual recurrence interval of events with a given magnitude. However, these large rainfall events make up only a very small proportion of all of the rainfall events.

Table 19 below, summarises the percentiles of rainfall events at Mahurangi site 644616. (Shamseldin, 2010).

Table 19: Mahurangi Rain event depth estimates and summary statistics for different percentiles

Percentile	Rain event depth (mm)
80%	23
85%	28.3
90%	35.1
95%	53.1

Table 19 illustrates that 95% of rainfall events have a rainfall depth equal to or less than 53.1mm. This compares to the 2 year ARI event that has a rainfall depth of 118mm (as shown in Table 4) at the same location.

This illustrates that while rainfall events such as the 2 year ARI are likely to occur over a 5 year construction period, over 95% of rain events will have less than half the rainfall depth of a 2 year ARI event.

7.2 Background sediment loads

The background sediment loads (i.e. the loads from the existing catchment) data is presented in WAFR 3 as mean annual loads (t/year) as well as event based loads (t) associated with selected 2 year, 10 year and 50 year ARI rainfall events.

While the focus in terms of sediment loads is typically within the Mahurangi River catchment, it is important to provide some context of the sediment loads from all of the sub-catchments draining to Mahurangi Harbour and these were also assessed by NIWA.

Figure 2-1 from the WAFR 3 shows the specific sub-catchment areas from which the catchment sediment loads were determined.

WAFR 3 confirms the following catchment annual background sediment loads:

- Pūhoi River Estuary 18,311 t
- Mahurangi Harbour (excluding the Te Muri Beach sub catchment) 45,931 t

Daily sediment loads for 2, 10 and 50 ARI rainfall events were also calculated.

These catchment-wide background sediment loads do not account for any forestry activity, in particular harvesting. We have reviewed previous studies of the harvesting period of the forestry cycle and confirm that this activity can produce a significant peak in sediment yields⁴.

The historic Auckland Regional Council 'Mahurangi Modelling Study Redwoods Site' (1995 and 1997) centred on the collection of water quality data for a period within a forested catchment prior to and during the harvesting period.

We understand that the erosion and sediment controls through this period were minimal and were based on the implementation of forestry slash bunds and water controls on track areas. This study illustrated a range of TSS water quality results, with some samples collected recorded close to 3,000 g/m³ which is considered to be very high. The conclusion reached was that the TSS levels increased and water clarity decreased with a corresponding increase in stream flows during harvesting operations.

During the actual harvesting period the Auckland Regional Council study was abandoned due to the significant erosion in the study catchment. This erosion created major sediment deposition in the stream systems which in turn lead to inundation of the sampling weirs that could not be reinstated. While water quality measurements were difficult to obtain at that specific time, the study confirmed that during the earthworks phase of the harvesting period, sediment yields were significantly higher than pre harvesting.

Further research undertaken by Hicks and Harmsworth (1989) related to the changes in sediment yield during logging at Glenbervie Forest, Northland New Zealand. This study involved sampling at the catchment outlets to assess sediment loads from 1981 to 1986.

In 1985 the mature forest was subject to earthworks associated with the harvesting activity. Sediment yields during the harvesting earthworks activity increased 100 fold from the pre harvest period. The actual harvesting operation itself was shown to have no noticeable change in sediment yield due to the significant impact that had already occurred during the preparatory earthworks phase.

While the background sediment loads determined by NIWA for this Project exclude the forestry harvesting and associated earthworks activities that could occur in this catchment, we consider such activities cannot be ignored as earthworks and harvesting operations is a reality within the current environment.

⁴ Hick, D.M and Harmsworth, G.R. (1989). Changes in Sediment Yield Regime During Logging at Glenbervie Forest, Northland, New Zealand.

These activities are ongoing and will occur within the existing environment and as shown by previous studies will lead to a probable increase in sediment yields over the forestry cycle. Figure 22 illustrates the sediment yield changes over the earthworks and harvesting period of the forestry cycle measured within Glenbervie Forest.

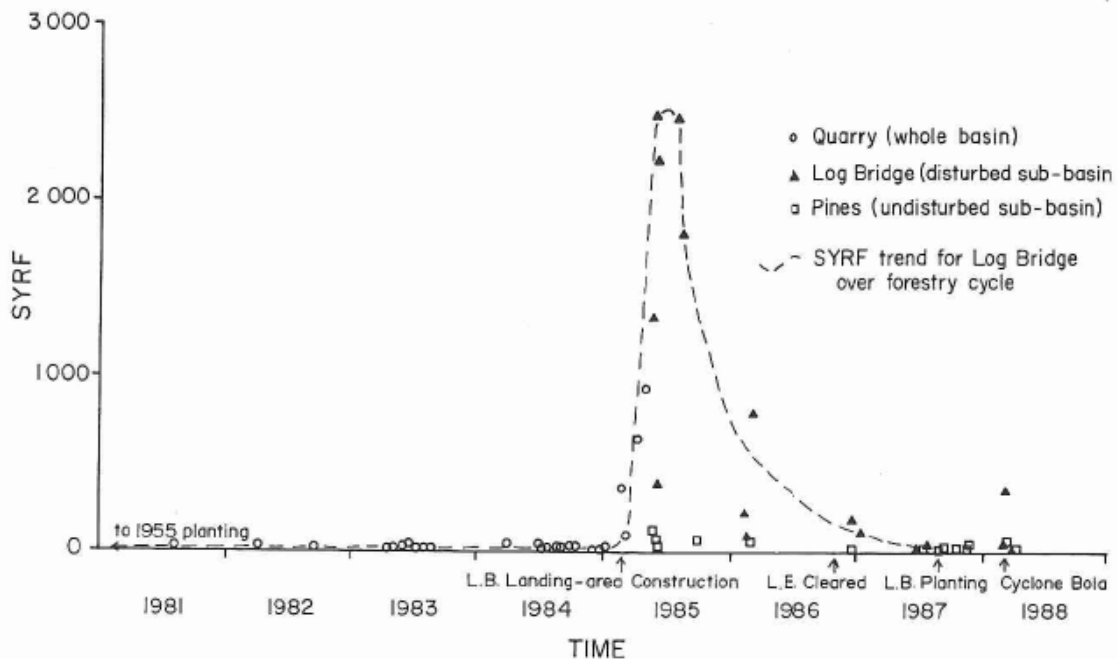


Figure 22: Sediment yields from Glenbervie Forest sub-catchment during harvesting

We have calculated sediment and nutrients loads entering the Mahurangi and Pūhoi estuaries from the Mahurangi and Pūhoi Rivers respectively as shown in WAFR 3. This is reported in Harper et al (2013).

The sediment and nutrient load includes the estimate for the background catchments related to the existing land-use, which is taken to describe the 'without project' scenario and a second scenario during the project construction.

To understand relative inputs from specific areas of the catchment and land-uses, river catchments are divided into sub-catchments. The background sediment loads reported for each sub-catchment outlet include mean annual loads as well as rainfall event-based loads associated with selected areas.

Mean annual loads for sub-catchments discharging to the Mahurangi estuary were calculated by aggregating the daily loads from the Basin New Zealand (BNZ) time-series and averaging over the 20-year period.

The sediment load estimates used existing information developed by NIWA for their BNZ modelling of the Mahurangi catchment in 1994/1995. For the Pūhoi River and Te Muri Beach catchments, where previous load estimates were unavailable, NIWA used the Catchment Landuse for

Environmental Sustainability model (CLUES; Semadeni-Davies et al., 2011, 2012) to generate the mean annual loads ratio against the Mahurangi River.

CLUES is a GIS-based framework which integrates a suite of related models to estimate mean annual sediment load, amongst other contaminants.

The event-based loads represent daily sediment loads discharged from each sub-catchment outlet with ARIs of 2, 10 and 50 years. These were calculated by performing a frequency analysis on the annual maximum series for the whole Mahurangi estuary, formed by selecting the highest daily loads from the BNZ time-series each year.

To generate the two, 10 and 50 year ARI loads for each sub-catchment, the sediment loads estimated from the distribution were scaled by the ratio of the mean annual sediment yield for each sub-catchment to that of the whole Mahurangi estuary. For the Pūhoi River and Te Muri Beach sub catchments, the Mahurangi River estimates were scaled.

One of our assumptions is that the land-use in the Mahurangi catchment in the 1994 to 1995 monitoring period will be similar to the land-use during the proposed construction period 2016 to 2021. In 1994 to 1995, the exotic forestry within the Pūhoi and Mahurangi forestry was approaching maturity with logging starting from 1997 onwards.

In 2013, most of the exotic forestry in the Mahurangi and Pūhoi catchments ranges from 12 to 16 years, with the majority of the forestry being approximately 12 years old. Therefore, while we do not discount the possibility of harvesting and associated earthworks occurring, we consider the land-use is likely to be similar because mature *Pinus radiata* is traditionally harvested at an age of 30 years or more. (S. Wilson 2013, Pers. Comm., 23 April).

We note however that from a forestry cycle perspective, earthworks and harvesting will occur at some point in time and therefore forms part of the background sediment load consideration.

7.3 GLEAMS modelling

During the early stages of the Project we recognised that NIWA had previous experience within the Mahurangi Harbour with land-use interpretation and contaminant modelling exercises and had a software license to use a mathematical model called GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), which has been adapted to help estimate the sediment yields entering receiving environments from land disturbing activities. GLEAMS is recognised as an appropriate model for this purpose and has been used on other roading projects such as the Waterview Tunnel.

NIWA was contracted by the Further North Alliance (FNA) to undertake an assessment of the sediment yields using GLEAMS. The findings and associated background calculations can be found in WAFR 3.

In addition to estimating construction sediment yields, NIWA also provided an assessment of the catchment wide background sediment loads and nutrient loads and concentrations in both the Mahurangi and Pūhoi catchments.

Previous studies were used by NIWA to assist with the above tasks, which included a modelling study of long-term sediment loads delivered to the Mahurangi Harbour in the late 1990s and also a field study undertaken to evaluate the performance of chemically treated sediment retention ponds in 2007.

These studies were also used to determine particle size distribution (PSD) in construction-related runoff and the fraction of sediment that is delivered to the coast. With PSDs taken from soil core samples from the Project, NIWA has determined the appropriate assumptions for the modelling exercise as detailed within WAFR 3.

7.3.1 GLEAMS model inputs

Soil texture is an important parameter for the GLEAMS model with finer textured soils (silts and clays) generating more sediment than coarser soil particles. We based the soil types used in the GLEAMS modelling on Project-specific borehole test results and the associated laboratory analysis of the particle size distribution (PSD) of these soils.

Details of the soil borehole locations and specific soil properties are discussed in WAFR 1. These boreholes were selected as representative of both the Hill and Flat Country Areas of the Project and were taken from various depths to represent any changes in soil strata that exist as deeper cuts are exposed.

Land cover inputs were based on existing land-use classes and from the Land Cover Database 2 (LCDB2). LCDB2 is a database developed by Ministry for the Environment for land-use classification, and as a baseline tool for analysis, monitoring and reporting of erosion risk indicators.⁵

Slope classes for the existing terrain were derived from GIS extraction of the Auckland Council LIDAR contours (2008). LIDAR contours are readily available and we also consider that they reflect the contours of the existing site adequately for the purpose of modelling.

The area of exposed open ground is also a fundamental input to the GLEAMS model. Construction staging assumptions used for the input into the GLEAMS model are discussed in Section 6 of this Report.

Sediment yield reduction factors for the SRPs and the various stabilisation methods were based on several studies in New Zealand, particularly from the ALPURT trials,⁶ Auckland Regional Council's (now Auckland Council) research on DEBs and stabilisation techniques and also the personal experience of Mr Graeme Ridley on the water quality measurements from the Long Bay development in Auckland.⁷

⁵ Ministry for the Environment online tools and guidelines. Accessible at <http://www.mfe.govt.nz/environmental-reporting/about/tools-guidelines/classifications/land/index.html>

⁶ Auckland Regional Council. TP227 – The use of flocculants and coagulants to aid the settlement of suspended sediment in earthworks runoff trials methodology and design (2004).

⁷ Long Bay Adaptive Environmental Monitoring and Management Response Plan data reported to Auckland Council 2010 to 2013.

Mr Ridley's experience with the Long Bay development includes results of specific monitoring of chemically treated SRPs through various rainfall events to measure the efficiency of the control measures. Due to the majority of the sampling results from the Long Bay development being related directly to storm events of 2 years or less, extrapolation of the efficiency data was undertaken to enable assessment of sediment yield reductions in larger storm events.

Table 20 below shows the efficiencies of a number of sediment control devices that we have used in our assessment. For the load reduction efficiency of stabilisation methods, we assessed previous Auckland Regional Council studies, which confirmed an 85% efficiency for mulching from a clay subsoil, and 93% was used for rock stabilisation.

Table 20: Sediment control device efficiencies

Sediment Control Device Type	Sediment Removal Efficiency (%) by Return Period		
	2year ARI	10year ARI	50year ARI
Super Silt Fence (SSF)	80%	65%	50%
Decanting Earth Bund (DEB) – Chemically Treated	90%	80%	60%
Sediment Retention Pond (SRP) – Chemically Treated	95%	85%	65%

WAFR 3 assesses the Focus Area Sediment Yields (FASY) that represent the Existing Sediment Yields (ESY) plus the additional Focus Area Construction Sediment Yields (FACSY) and Post Construction Sediment Yields (PCSY) from each of the Focus Areas. Figure 23 below illustrates the terminologies used in this Report to refer to the sediment yields from the Focus Areas.

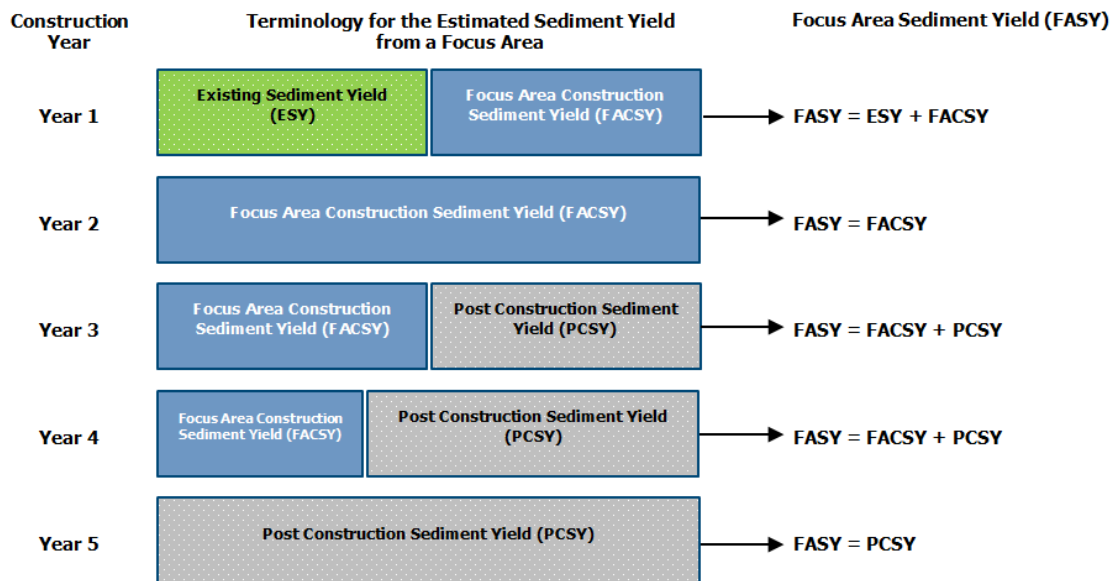


Figure 23: Sediment yield terminology used in this Report (Further North, 2013)

We note that WAFR 3 clarifies the variations in additional sediment yields between years. This reflects the difference in the extent of construction activities such as the largest areas of exposed earth. The largest area of works is expected to occur in 2019 (based on the conceptual 5 year construction methodology with a 2016 commencement date).

WAFR 3 also notes that the FASY in the 10 year construction scenario is greater than the 5 year construction scenario as the estimates take account of the sediment yield generated from all land covers over the 10 year period.

The construction phase sediment yields were estimated by GLEAMS which applies a long-term climate record to unique combinations of land cover, soil type and slope. GLEAMS outputs result in a long term series of daily sediment yields per unit area, which are aggregated to provide an overall annual sediment yield.

Running the GLEAMS model requires a series of assumptions to be made, in addition to inputs that focus on the construction related activity and in particular the ESC measures and methodologies to be used. These assumptions and inputs are tested, and validated where possible, through the conceptual construction programme and the model then activated. The GLEAMS model assumptions are covered in WAFR 3.

The sediment yields were estimated using GLEAMS for the Project's two Focus Areas with two different scenarios representing the 5 year and 10 year conceptual construction periods, which are detailed in Appendix A of WAFR 3.

The daily sediment yields estimated for the conceptual construction periods reflect not only the amount of earthworks area exposed but also the return period of the rainfall events that may be expected during the months when the earthwork areas are exposed.

7.3.2 GLEAMS sediment yield results

WAFR 3 provides the mean annual FASY for the 5 year and 10 year conceptual construction programme for both the Hill Focus Area and the Flat Focus Area and these have been extracted and are included in Table 21 and Table 22.

Table 21: Focus Area sediment yield results from the GLEAMS model for the 5 year conceptual programme (WAFR 3)

Sediment Yield (t) for the 5 year conceptual programme						
Hill Focus Area				Flat Focus Area		
Year	Background	FASY	Additional	Background	FASY	Additional
2016	478	563	85	435	472	37
2017	478	853	375	435	532	97
2018	478	1413	935	435	533	98
2019	478	1953	1475	435	560	125
2020	478	1598	1120	435	483	48
5 year total	2390	6380	3990	2175	2581	406
Mean annual	478	1276	798	435	516	81

Table 22: Focus Area sediment yield results from the GLEAMS model for the 10 year conceptual programme (WAFR 3)

Sediment Yield (t) for the 10 year conceptual programme						
Hill Focus Area				Flat Focus Area		
Year	Background	FASY	Additional	Background	FASY	Additional
2016	478	525	47	435	442	7
2017	478	642	164	435	431	-4
2018	478	720	242	435	431	-4
2019	478	773	295	435	450	15
2020	478	1320	842	435	456	21
2021	478	1329	851	435	479	44
2022	478	1384	906	435	456	21
2023	478	1412	934	435	483	48
2024	478	1570	1092	435	483	48
2025	478	1777	1299	435	483	48
10 year total	4780	11451	6671	4350	4595	245
Mean annual	478	1145	667	435	459	24

We note that the FASY does not represent the full construction related sediment yields as illustrated in Table 31 of this Report. When considering the overall increase in sediment loads on a catchment-wide basis, WAFR 3 provides a comparative analysis between the FASY and the background loads for the Mahurangi River catchment. This is summarised in Table 23.

Table 23: GLEAMS Focus Area sediment yield results for the Mahurangi River

5 year conceptual programme	Background load – Mahurangi River	FASY plus background load	Percentage increase
Total Sediment Load (t)	60965	65361	7
Mean Annual Load (t)	12193	13072	7
10 year conceptual programme	Background load – Mahurangi River	FASY plus background load	Percentage increase
Total Sediment Load (t)	121930	128846	6
Mean Annual Load (t)	12193	12885	6

Importantly the above overall percentage increase in sediment load is related to the Mahurangi River sub-catchment only and does not represent the full Mahurangi Harbour as shown in Table 24 below.

When considered in the context of the overall harbour environment (excluding the Te Muri Beach sub-catchment area which discharges into the open coast) the sediment load percentage increase for the FASY for the Mahurangi Harbour environment is less than the Mahurangi River at 2% for the 5 year and 1.5% for the 10 year construction programme.

Table 24: GLEAMS sediment yield results for the Focus Areas and the Mahurangi Harbour (Source)

5 year conceptual programme	Background load – Mahurangi Harbour	FASY plus background load	Percentage increase
Total sediment load (t)	229655	234050	2
Mean annual load (t)	45931	46810	2
10 year conceptual programme	Background Load – Mahurangi Harbour	FASY plus background load	Percentage increase
Total sediment load (t)	459310	466226	1.5
Mean annual load (t)	45931	46623	1.5

A similar exercise can be undertaken for the Pūhoi River catchment. We have adopted the assumption that the entire Project within the Pūhoi catchment will yield sediment at the same rate as the Hill Focus Area as there are similar soil types, slopes and climate.

Table 25: Sediment yield for the Pūhoi River

5 year conceptual programme	Background load – Pūhoi River	FASY plus background load	Percentage increase
Total sediment load (t)	91555	95545	4.5
Mean annual load (t)	18311	19109	4.5

In addition as part of the above sediment yield calculations, the corresponding discharge TSS concentrations have been calculated over a 24 hour period for the 2 year, 10 year and 50 year ARI rainfall events for the periods when the maximum earthworks area will be exposed.

The TSS concentrations are based upon a frequency analysis of the full river flow record of the Mahurangi River and identification of rain events that represent the highest peak flow. Hydrographs were developed by NIWA for each of the three events and the fraction of the total

daily flow in each hour was calculated, which in turn was used to calculate the TSS concentration for that same period.

The assessment of the modelled TSS concentrations is discussed in detail within the Freshwater and Marine Ecology Assessment Reports.

7.4 USLE modelling

In parallel to the GLEAMS modelling, we undertook Universal Soil Loss Equation (USLE) calculations to provide a level of confidence and a check of the results of the GLEAMS model.

USLE calculations can also be performed more quickly than the GLEAMS model, allowing us to test the sensitivity to various input parameters, without the need to re-run the GLEAMS model.

The USLE calculation was developed in the USA by the US Department of Agriculture to estimate sheet and rill erosion, primarily for agricultural practices. Over many years it has been developed and tested within New Zealand as a suitable sediment yield estimation tool for a range of land disturbing activities, including earthworks.

Auckland Council accepts the use of the USLE calculation for this purpose of estimating sediment yield and requires USLE calculations to support the majority of consent applications associated with land disturbing activities.

In undertaking the USLE calculations we have followed the procedures within Auckland Council guidance documents and also the 'Erosion and Sediment Control Handbook' by Steven Goldman, Katharine Jackson and Taras Bursztynsky. The USLE predicts average annual sediment yield and a key limitation of the USLE is that it does not account for unusually higher than normal rainfall or discrete rainfall events.

We note that the USLE is often considered to under-estimate actual sediment yields from land disturbing activities. However, Mr. Graeme Ridley's recent personal experience within the Long Bay catchment, has shown the opposite to be true. As an example over the 2011/2012 earthworks season, 9 rain events with rainfall depths in excess of 25mm in 24 hours were recorded and actual measured sediment yields of 3.6 t were recorded. This result compared to the USLE estimate of 43.8 t for the same period with a maximum 20.2 ha of earthworks (as discussed in Section 5.4.1 of this Report).

This difference in the actual and calculated sediment yields largely reflects the innovative practices and management methods that were applied at the Long Bay development. However, it clearly illustrates that results better than those predicted by the USLE can be achieved by appropriate ESC and site management.

It is recognised within the industry that the primary purpose of USLE is as a comparative tool to gain an appreciation of the expected increase in catchment-wide sediment yields as a result of earthworks activity, thus providing an assessment of the risk of sediment generation and yields.

It can also assist with identification of higher risk areas and the design and implementation of appropriate ESCs required to manage risks to the receiving environment from sediment discharges.

7.4.1 USLE model inputs

Our USLE calculations largely adopted the same input parameters that were used for the GLEAMS model (detailed within WAFR 1). The rainfall data used however differs, in that GLEAMS uses an historic 50 year rainfall record, while for the purpose of the USLE calculations, we used a 2year 6 hour duration storm event (based on HIRDS version 3) with recognition that this is considered to represent a rainfall event with a high erosive force and intensity.

This 2 year 6 hour duration rainfall depth is accepted by Auckland Council as the appropriate duration and intensity to determine sediment yields. We also consider that based on the construction programme and risk profile of rain events outlined earlier in this section, that the 2year 6hour duration event is appropriate.

Within the USLE calculation we have also applied a specific slope length (LS) factor that reflects the actual slope length that will be implemented in practice onsite.

We have also applied a vegetative cover factor (C factor) and an erosion control factor (P Factor), which takes account of the surface condition of the earthworks prior to the rain event. These factors have been 'tested' from a constructability perspective and are considered realistic for the Project.

7.4.2 USLE sediment yield results

Specific USLE calculations have been included within the WAFR 1. These calculations have been based on the two construction period scenarios 5 and 10 years within the two Focus Areas as identified in Section 1.7 of this Report. The scenarios modelled are:

- 5 year construction period for the Hill Focus Area, Moirs Hill Road Sector (Construction Zone 7B);
- 10 year construction period for the Hill Focus Area, Moirs Hill Road Sector (Construction Zone 7B);
- 5 year construction period for the Flat Focus Area, Perry Road Sector (Construction Zone 9); and
- 10 year construction period for the Flat Focus Area, Perry Road Sector (Construction Zone 9).

For ease of reference we have shown the comparative FASY between GLEAMS (Mean Annual) and USLE (Average Annual) in Table 26.

Table 26: FASY estimates from GLEAMS and USLE

FASY for the 5 year construction programme					
Hill			Flat		
Year	GLEAMS	USLE	Year	GLEAMS	USLE
Year 1	563	670	Year 1	472	380
Year 2	853	1171	Year 2	532	483
Year 3	1413	1494	Year 3	533	558
Year 4	1953	1931	Year 4	560	586
Year 5	1598	2067	Year 5	483	662
Total (t of sediment)	6380	7333	Total (t of sediment)	2580	2669
FASY for the 10 year construction programme					
Hill			Flat		
Year	GLEAMS	USLE	Year	GLEAMS	USLE
Year 1	525	648	Year 1	442	348
Year 2	642	980	Year 2	431	470
Year 3	720	997	Year 3	431	399
Year 4	773	979	Year 4	450	630
Year 5	1320	1139	Year 5	456	482
Year 6	1329	1330	Year 6	479	677
Year 7	1384	1950	Year 7	456	512
Year 8	1412	1730	Year 8	483	662
Year 9	1570	1868	Year 9	483	662
Year 10	1777	1868	Year 10	483	662
Total (t of sediment)	11452	13489	Total (t of sediment)	4594	5504

These results illustrate the comparative assessment between GLEAMS and the USLE and provide confidence that, while we have used the GLEAMS results in our assessment process, USLE

calculations provide a tool that can be used for risk assessment and sensitivity analysis throughout the construction phase of the Project.

While the USLE provides a comprehensive overview of potential FASY, we recognise that this is only theoretical, and the maximum value is gained through the comparative analysis of the yields calculated.

Throughout the Project, and during the detailed design process, we recommend that the USLE calculations should be used as part of the risk assessment to refine the ESC measures for the Project.

7.5 GLEAMS and USLE analysis outcomes

GLEAMS modelling estimated the FASY using a 5 year and a 10 year conceptual construction periods and also estimated the sediment generated during the greatest extent (peak) of open active earthworks in the Mahurangi and Pūhoi catchments for the 5 year and 10 year conceptual construction programmes.

We have used the estimate of FASY generated during the peak open earthworks for the water quality and ecological assessment of effects as outlined within the Freshwater and Marine Ecology Assessment Reports.

The modelling developed overall background sediment loads for the Pūhoi catchment, but did not calculate a construction sediment yield for this catchment. The Focus Areas, discussed in Section 1.7 of this Report are both within the Mahurangi catchment.

The comparative USLE analysis has confirmed that the predicted sediment yield per unit area from the Pūhoi catchment south of Moirs Hill is similar to the sediment yield per unit area calculated in the Hill Focus Area.

To estimate the construction sediment yield for the Pūhoi catchment, we have assumed that the FASY generated in the Hill Focus Area is equivalent to the yields generated from the same area of active earthworks in the Pūhoi catchment.

The FASY were calculated with and without ESC treatment scenarios. 'Without treatment' is considered to be if the earthworks were to occur with no ESC measures in place and 'with treatment' is the same earthworks but with water management measures implemented, as outlined in Section 6 of this Report.

The performance of the ESC measures used for the assessment of effects are summarised in within Section 7.3.1 of this Report.

The catchment sediment modelling does not account for sediment generated from slope failures during construction or by stream works. Within each catchment there are a large number of small tributaries and some larger rivers to be crossed. There is also a need for either temporary or permanent diversions of some stretches of watercourse. The assessment of the effect of sediment generated during stream work has focused on considering the scale of stream works in relation to the earthworks, the time of the year when works will occur, sequencing and staging considerations

and the proposed mitigation methods. We assess that the exclusion of the streamworks and slope failure activity does not compromise the sediment yield risk assessment process.

Assessing the change in sediment yield will help to understand whether the Project is likely to change the quality of water in relation to colour, clarity, amenity values and contact recreation. The increase in sediment is also useful in understanding the impact on freshwater and marine ecosystems, which are assessed in the Freshwater and Marine Ecology Assessment Reports.

From the modelling exercise undertaken, we note the following with respect to sediment yields:

- i. For the 5 year Hill Country scenario construction period, the last 3 years of construction illustrate a higher FASY than the first two years. This effectively is due to the larger open areas of earthworks over this period. From a risk management perspective, progressive stabilisation of the open areas of earthworks will be critical in ensuring that erosion is minimised.
- ii. The PCSY on completion of the earthworks in the Hill Country scenario are higher than the pre earthworks (forestry) background yields. The sediment modelling is based on revegetation of the completed earthworks with a mulch cover which will in turn revert to pasture. The GLEAMS model predicts a higher sediment yield from pasture than forestry (for a given slope class). The road footprint will become stabilised with basecourse which is not modelled within the sediment calculations. This will reduce sediment yields as works progress and again this progressive stabilisation is critical to the reduction in sediment generation.
- iii. Where revegetation and landscaping is to occur this should be implemented on a progressive and ongoing basis to minimise the sediment generation from the completed areas.

For ease of modelling, the GLEAMS and USLE both assume that the current slope class at the commencement of earthworks will remain - representing a worst case scenario. In reality as gully systems are filled, and cut operations continue, the slope of the original contour will reduce. As detailed in Section 3 of this Report, the slope is one of the key determining factors in sediment generation and therefore a reduction in the slope angle will have a dramatic effect on sediment yields. Table 27 below illustrates that a 50% reduction in the original slope angle as earthworks progress results in a 67% reduction in sediment yields for that calendar year. WAFR 1 provides these associated yields.

Table 27: Slope class change sediment yield example from USLE

Zone 7B – 5 Year Construction Period	FASY with Original Slope Class (t) – USLE Calculations	FASY with 50% reduction in Slope Class (t) – USLE Calculations	Percent reduction in FASY
Period 2018	1493	498	67%

Irrespective of the reduction in slope angle, as works progress, the steeper areas of the site are identified as the higher sediment yield areas. From a risk management perspective these areas will have a large degree of focus for pre rainfall inspections, maintenance of control measures,

progressive stabilisation and ensuring sequencing of works is such that these areas are exposed during the summer months only. These steeper areas of the site can be clearly identified within the slope maps provided in Drawings ES-101 to ES-117. These drawings also show the varying slopes in the terrain.

The Project area has been classified into slope classes split into 3° intervals (i.e. from 0-3°, 3°-6° and up to 30+ degrees based on LIDAR data), as shown in Drawings ES-101 to ES-117. We have observed from the GLEAMS and USLE calculations that those areas with slopes greater than 15° present a higher risk of sediment yield. An example of this is illustrated for Cut 5 within the Hill Focus Area in Table 28.

Table 28: Sediment yield from Cut 5 in the Hill Focus Area

Zone 7B – 5 Year Construction Period	Cut 5 Location January to March 2018	Cut 5 Location April to October 2018
FASY for Period (t)	37.7	75.4
FASY for Slopes above 15 degrees (t)	35.5	71.0
Percent of FASY from Slopes above 15 degrees	94%	94%

Conceptual methodologies, as discussed in Section 6 of this Report, have been developed in recognition of the increased sediment generation risk from the steeper slopes. As detailed and illustrated above, during earthworks activities, these slopes will be reduced and batter slopes progressively stabilised. It is also important that these steeper areas receive a higher degree of focus during construction so that the slope lengths are reduced and progressive stabilisation occurs on a proactive and ongoing basis.

Over the entire Project footprint, we have assumed that each area will remain open for a period that is consistent with the conceptual construction programme included in the construction section of the AEE, which reflects the sequencing of the likely mass-haul of cut and fill operations. Best practice techniques will be employed during all works with particular emphasis on higher risk activities and locations.

As batters are established they will be topsoiled and seeded and mulched to minimise erosion and sediment generation. For the management of monoslope construction, where the grade is such that topsoil placement is not feasible, stabilisation will take place at the best degree possible on the rock face. The management of these is discussed within Section 6 of this Report.

Emphasis will be placed upon the monitoring and maintenance of all sediment retention controls installed and the methodologies used with particular attention being paid to these areas both before and after rain events. Reference should also be made to the adaptive monitoring programme as outlined in Section 8 of this Report.

7.6 Sediment yield extrapolation

The FASYs that have been calculated from the GLEAMS and USLE assessments are summarised above. As detailed, the sediment yield assessment is based on two Focus Areas with a 5 year and a 10 year conceptual construction programme.

From the USLE calculations we have determined the average annual sediment yields for the various scenarios. Based on these calculations we are able to assess the average sediment yields that result from the Hill Focus Area and also the Flat Focus Area, which in turn enable us to extrapolate these results to the wider project.

For the purpose of this extrapolation we have included the FACS, PCSY and the ESY within the Focus Areas. The overall sediment yields are illustrated in Table 29 and Table 30 below.

Table 29: Average annual FASY extrapolation from USLE 5 year scenario

Hill – 5 year construction period	Contributing exposed earthworks area (ha)	FASY (t)	Flat – 5 year construction period	Contributing area (ha)	FASY (t)
2016	16.84	670	2016	22.96	380
2017	26.04	1171	2017	31.84	483
2018	44.54	1494	2018	22.19	558
2019	44.18	1931	2019	16.07	586
2020	22.59	2067	2020	NA	NA
Total	154.2	7333	Total	93.06	2007
Average Annual Sediment Yield	47.6t/ha/year		Average Annual Sediment Yield	21.6t/ha/year	

Table 30: Average annual FASY extrapolation from USLE 10 year scenario

Hill – 10 year construction period	Contributing exposed earthworks area (ha)	FASY (t)	Flat – 10 year construction period	Contributing area (ha)	FASY (t)
2016	16.84	648	2016	22.96	348
2017	16.84	980	2017	22.96	470
2018	26.04	997	2018	31.84	399
2019	31.79	979	2019	13.08	630

Hill – 10 year construction period	Contributing exposed earthworks area (ha)	FASY (t)	Flat – 10 year construction period	Contributing area (ha)	FASY (t)
2020	31.79	1139	2020	22.19	482
2021	44.18	1330	2021	16.07	677
2022	12.75	1950	2022	16.07	512
2023	12.75	1730	2023	NA	NA
Total	192.9	9753	Total	145.2	3518
Average Annual Sediment Yield	50.6t/ha/year		Average Annual Sediment Yield	24.2t/ha/year	

We have averaged between the 5 and the 10 year periods and from the above tables it is assessed that for the Hill Country a sediment yield of 49.1 t/ha/year and for the Flat Country a sediment yield of 22.9 t/ha/year is representative.

As detailed above, this FASY includes the existing sediment yield that will result from stabilised areas leading up to the period of full stabilisation and therefore it is considered to be a conservative calculation.

From the construction programme, from which we have undertaken the GLEAMS and USLE calculations, we have derived a maximum earthworks exposed area of 41 ha within the Hill Country and 21.5 ha within the Flat Country for a 5 year construction programme.

Following refinements of the design throughout the Project assessment phase, the construction programme has evolved. This is detailed within the construction section of the AEE and represents what is considered a practical construction programme. We have checked the new construction sequence and from this we have determined the estimated annual maximum exposed open area of earthworks. This area is less than the 41 ha and 21.5 ha in the Hill Country and Flat Country areas respectively that we originally modelled.

By extrapolation of the Hill Country and Flat Country sediment yields, both of which were within the Mahurangi Catchment, we are able to assess the corresponding sediment yields for the entire Project earthworks footprint including the Pūhoi catchment. The results are presented in Table 31 below.

The sediment yields included in this table represent those calculated using the earthworks footprint only and they do not include the background sediment loads.

For the purposes of this assessment we have also assumed that once the earthworks are completed and have been fully stabilised, sediment yields from these areas will be minimal in subsequent years.

We assess that with the progressive nature of the Project construction with hard fill, landscaping and revegetation programmes that this assumption is realistic. We do however caution that the sediment yields calculated are theoretical and we consider the actual sediment yields are likely to be lower than those shown in Table 31.

Table 31: Sediment yield extrapolation for the Project

Discharge point -->		Pūhoi River					Mahurangi River				Construction sediment yield yearly total (t)
Earthworks construction zone -->		1	3	5	6	7A	7B	9A	9C	11	
		Pūhoi Hills					Mahurangi Hills	Mahurangi Flats			
Open areas (ha)	Year 1	0.0	11.9	9.4	0.0	3.2	14.2	1.2	0.0	1.7	
	Year 2	0.0	1.0	20.8	0.0	16.3	19.3	13.1	0.0	9.4	
	Year 3	0.0	8.3	18.4	2.4	11.6	43.8	9.7	6.1	8.5	
	Year 4	1.5	4.2	9.5	0.0	7.3	24.1	0.0	23.6	0.0	
	Year 5	0.0	0.0	0.0	0.0	2.6	9.9	3.4	16.2	7.5	
Construction sediment yield (t/ha/year)		49.1	49.1	49.1	49.1	49.1	49.1	22.9	22.9	22.9	
Total construction sediment yield (t)	Year 1	0.0	584.8	459.6	0.0	157.4	699.1	27.6	0.0	38.3	1966.9
	Year 2	0.0	49.3	1020.2	0.0	801.3	946.6	299.8	0.0	215.9	3333.1
	Year 3	0.0	407.1	905.8	118.2	569.6	2151.2	223.1	139.5	194.9	4709.6
	Year 4	71.8	208.3	465.4	0.0	360.6	1182.1	0.0	541.4	0.0	2829.7
	Year 5	0.0	0.0	0.0	0.0	127.5	486.7	78.7	370.1	172.2	1235.3
	Total for Zone	71.8	1249.6	2851.1	118.2	2016.4	5465.8	629.3	1051.1	621.3	14074.5
	Totals	6307.1					5465.8	2301.6			

Overall we consider the maximum open area of earthworks as modelled, allows the practical completion of the earthworks for the Project construction to be carried out within the conceptual programme.

We note that the Marine Ecology Assessment Report assesses that the only potentially significant effect to marine ecological values within both the Pūhoi Estuary and the Mahurangi Harbour from the Project is the occurrence of a large rainfall event (e.g. 50 year ARI) during peak open earthworks. We assess that the probability of such an event occurring during the maximum open area of earthworks during the construction period is very low.

Based on the maximum open area of earthworks, we have assessed that a 41 ha open area limit is appropriate for the Pūhoi Catchment. For the Mahurangi Catchment, we have assessed that a maximum open area of earthworks of 41 ha and 21.5 ha applies in the Hill Country and Flat Country respectively.

However, in order to provide flexibility to the construction contractor during construction we have illustrated in Figure 24 that other open area of earthworks combinations within the Hill Country and Flat Country areas within the Mahurangi Catchment can apply without affecting the combined sediment yield.

We have calculated that the sediment yield from a representative 1 ha of open area of earthworks in the Flat Country is approximately 46.7% of the sediment yield from a corresponding representative 1 ha of open area of earthworks within the Hill Country and therefore, if required, the extent of open areas of earthworks between the Hill Country and Flat Country can be adjusted accordingly to reflect working practices and sequencing of works during construction.

For example, a 1ha increase in open area of earthworks in the Flat Country (above the 21.5ha limit discussed above) will require a corresponding 0.467ha reduction in open areas of earthworks in the Hill Country.

The reverse situation is equally applicable, in that a 1ha increase in open area of earthworks within the Hill Country, (above the 41ha limit discussed above) will require a corresponding 2.14ha reduction of open area of earthworks in the Flat Country, subject to a maximum open area of earthworks within the Hill Country of 51.05ha which will result in no earthworks activity being permitted to take place within the Flat Country during the same time period.

Project Earthwork Open Area Limitations

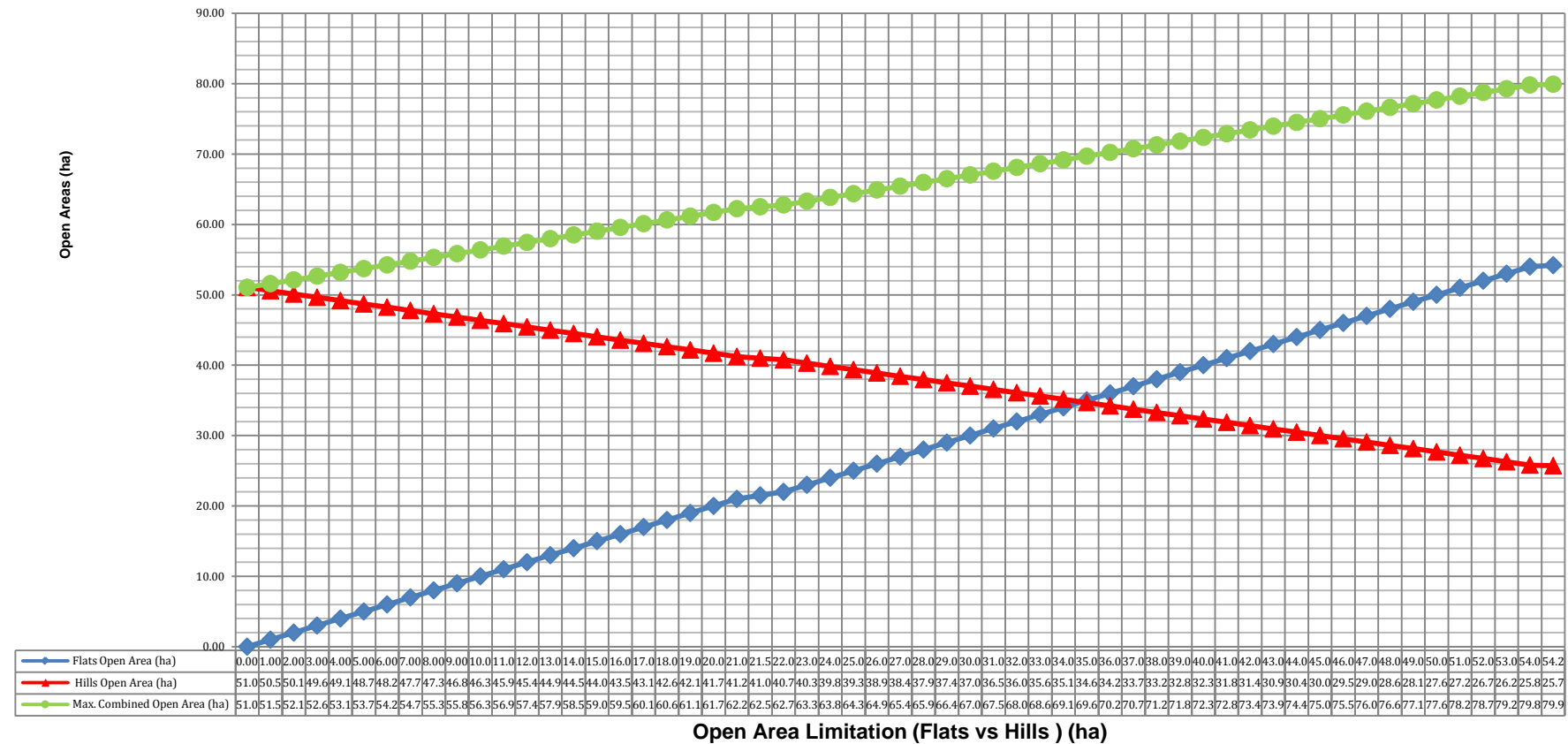


Figure 24: Earthwork Open Area Limitations for the Project

It is recommended that a limit on the open area of earthworks be placed on the Project, which reflects the results of the modelling undertaken and illustrated in Figure 25 above.

We also recommend that the ESC measures should be subject to an adaptive monitoring programme, which over the duration of the Project will inform relevant parties as to the effects from such an open area of earthworks.

If this adaptive monitoring programme illustrates that environmental outcomes (as determined through the adaptive monitoring) are being achieved then the Consent Holder will have the ability to amend the open areas of earthworks.

With respect to spoil volume, as discussed within the construction section of the AEE, we assess that this has minimal, if any, impact on the Project from a sediment yield perspective. The sediment yield is driven by the extent of open area of earthworks and spoil will only be able to be disposed of within these open area limitations. The environmental effects will therefore remain as assessed.

We further note that from a constructability perspective it is unlikely that the Project will be implemented with such large excess spoil volumes. Experience from other projects, including discussions with contractors within the Auckland region, confirms that value engineering will occur which will minimise these spoil volumes and hence reduce the requirement for spoil sites.

We acknowledge that some spoil sites are inevitable and have developed conceptual ESC methods and management techniques for Spoil Site 10, the detail of which is contained in Section 6 of this Report.

7.7 Sediment modelling interpretation

The increase in sediment yield during construction, results in an increase in sediment load in the receiving environments. Increased sediment loads during rainfall events, are useful in understanding the effects of the discharge of sediment on ecosystems, existing water users and aesthetics and amenity. Increased average annual sediment load provides an understanding of the potential cumulative effects over a longer time horizon.

Assessment of available water quality data, as outlined in WAFR 4, shows that freshwater systems within the Mahurangi and Pūhoi Catchments have slightly elevated TSS loads and therefore are slightly turbid, even in low flow conditions.

7.7.1 Increase in sediment concentrations from earthworks

The background sediment load has been distributed over the flow hydrographs in Figure 25 to Figure 29. The shape of the flow hydrographs is related to measured hydrograph shapes, and is not indicative of any impact of construction or that the SRPs would have on the hydrology. The 'tails' at the end of the hydrographs in Figure 26, Figure 27 and Figure 28 are representative of a hydrograph shape in a measured event in the existing situation, rather than being related to construction effects.

The construction sediment yield has also been distributed across the flow hydrograph using the same distribution as the background load. This is a simplification, and we would expect some alteration in the shape of the construction hydrograph due to the attenuation in SRPs. SRPs may continue to discharge for a period of time after the peak of an event has passed. This estimate of the increased duration of an SRP discharge has been based on experience of the Long Bay Development in Auckland as illustrated in Section 8 of this Report.

We would also expect the TSS concentration to return to background concentrations between rainfall events. The difference between the background and construction concentrations at the beginning and end of the events plotted on Figure 27 to Figure 29 is related to the scaling method, rather than indicating a prolonged increase in background TSS concentrations.

Figure 27 to Figure 29 below illustrate the modelled increase in TSS and turbidity over the 2 year ARI event, for the 5 year construction period. Data has been analysed for the 2, 10 and 50 year ARI events for both the 5 year and 10 year construction periods to inform the assessment of effects. The concentrations for the other ARI events are provided in WAFR 3.

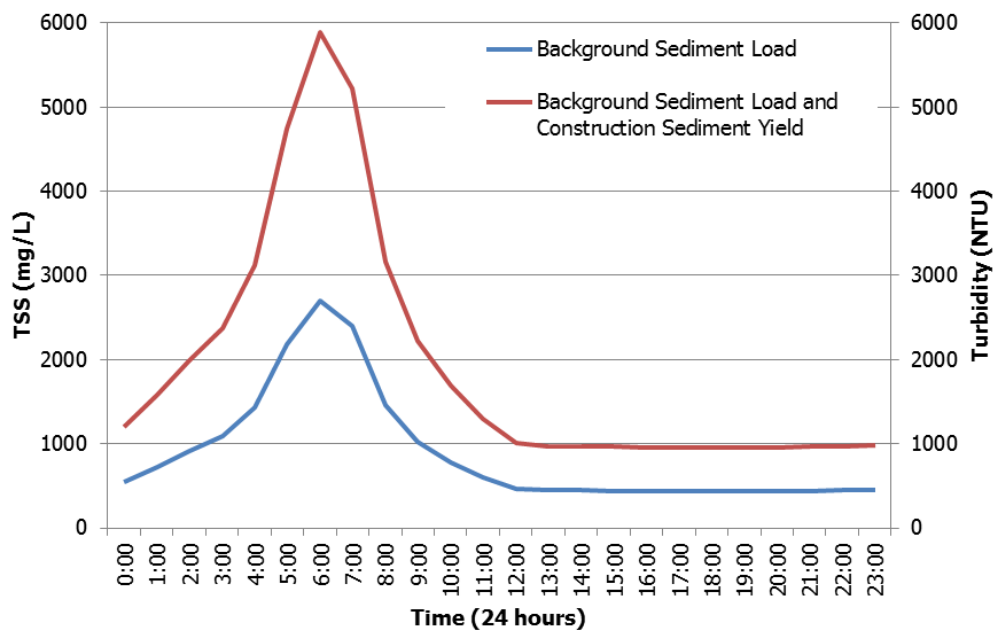


Figure 25: AC-FHQ Hourly TSS and turbidity concentrations five year construction of a 2 year ARI event

Site AC-FHQ is an upper Mahurangi Catchment tributary. The site receives runoff from most of the Hill Focus Area. At this site, the peak construction activity in the Hill Focus Area forms approximately 10% of the overall Mahurangi Catchment. A large increase in TSS concentrations and turbidity levels relative to background is predicted at this site.

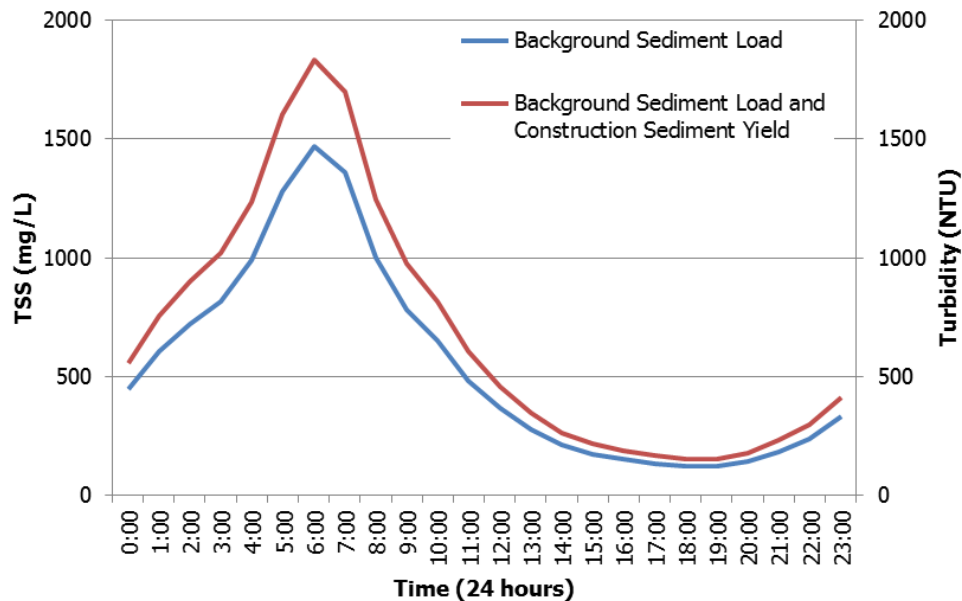


Figure 26: MW site hourly TSS and turbidity concentrations five year construction of a 2 year ARI event

Site MW Mahurangi is a mid-Mahurangi Catchment tributary and receives flow from both the Mahurangi Left and Right branches. It receives runoff from the all of the Hill Focus Area and the majority of the Flat Focus Area. The construction TSS concentrations and turbidity levels in this part of the catchment is a smaller proportion of the background levels.

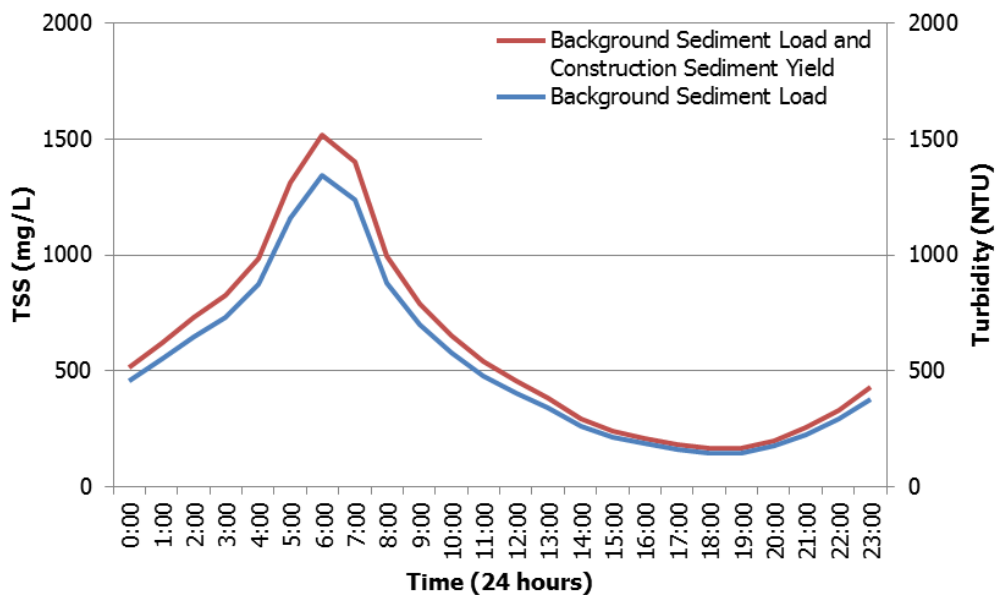


Figure 27: Mahurangi Mouth site hourly TSS and turbidity concentrations five year construction of a 2 year ARI event

The Mahurangi mouth receives the construction runoff from the coincident works in both the Hill and Flat Focus Areas. The construction TSS concentrations and turbidity levels in this part of the catchment is a smaller proportion of the background levels.

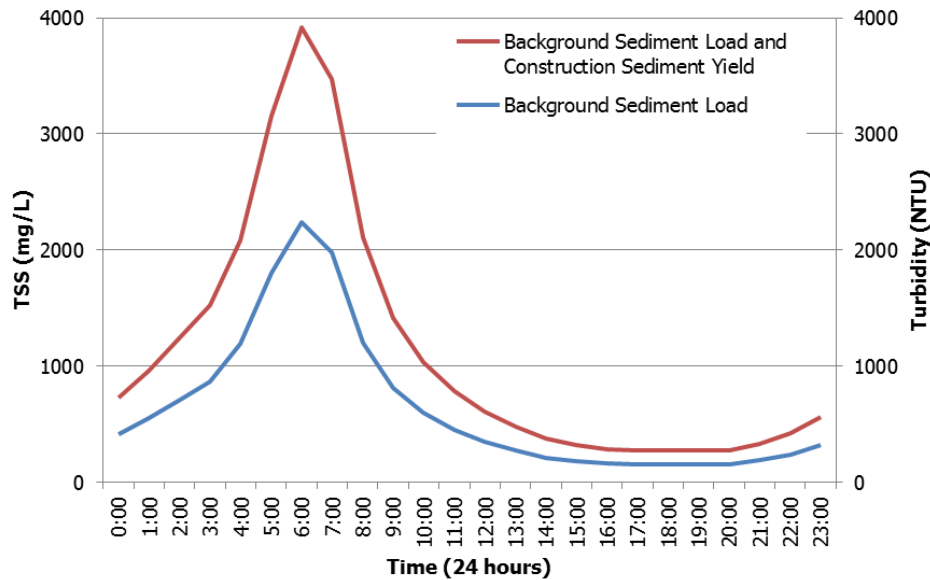


Figure 28: P10 site hourly TSS and turbidity concentrations five year construction of a 2 year ARI event

The P10 site receives the construction runoff from the Hill Focus Area. The sediment yield TSS concentrations and turbidity levels in this part of the catchment is a relatively large proportion of the background loads.

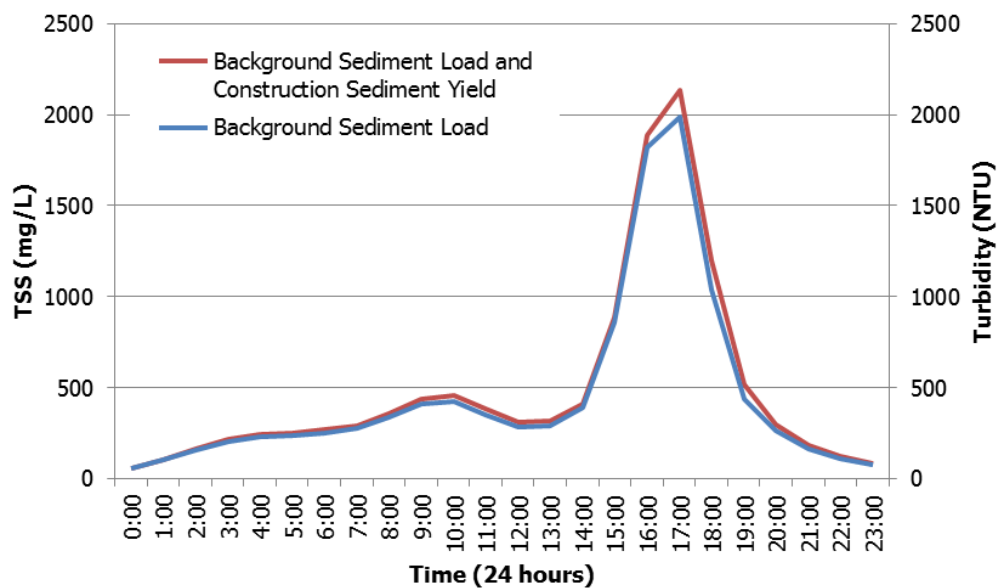


Figure 29: Pūhoi Mouth site hourly TSS and turbidity concentrations five year construction of a 2 year ARI event

The Pūhoi mouth receives construction runoff extrapolated from the Hill Focus Area. TSS concentrations and turbidity levels in this part of the catchment is a smaller proportion of the background loads.

7.7.2 Increase in sediment load from earthworks

Sediment entering the freshwater catchment will change as the Project progresses, with an increase in sediment yields, above those generated in the existing catchment, being anticipated during rainfall events. However the sediment loads in the Rivers that are predicted to occur during construction could also occur during a rainfall event within the existing catchment.

We have assessed the sediment load for specific events during the construction of the Project. This assessment is based on specific frequency events measured as ARI in years with specific likelihoods measured as an annual exceedence probability (AEP).

The AEP describes the probability that an event of a given ARI size will occur one or more times in any given year. Table 32 and Table 33 and show for specific 2, 10 and 50 year ARI events, the AEP of those events occurring during construction and the sediment load associated with that event. The tables also present the event frequency and likelihood that would generate the equivalent sediment load under the current background conditions.

Table 32: Mahurangi River estimated change in ARI and AEP over background conditions for 2, 10 and 50 year ARI construction daily loads (for maximum earthworks area and five year construction period)

Construction			Background without project		
ARI of event (years)	AEP of event occurring (%)	Event load (kg)	ARI of event (years)	AEP of event occurring (%)	Event load (kg)
2	39%	2826	2	39%	2826
10	10%	8249	13	7.4%	8249
50	2%	21844	68	1.46%	21844

Table 33: Pūhoi estimated change in ARI and AEP over background conditions for 2, 10 and 50 year ARI construction daily loads (for maximum earthworks area and five year construction period)

Construction			Background without project		
ARI of event (years)	AEP of event occurring (%)	Event load (kg)	ARI of event (years)	AEP of event occurring (%)	Event load (kg)
2	39%	4945	2	39%	4945
10	10%	11635	11	8.7%	11635
50	2%	30079	58	1.7%	30079

Table 32 and Table 33 show that when the predicted sediment loads for the 2, 10 and 50 year events (which include the sediment yields from the Project) are compared with the background sediment loads in the Mahurangi and Pūhoi Rivers, the construction events' loads are equivalent to loads generated during slightly less likely events in the background case. For example, on the Mahurangi River the sediment load with average return period of 10 years has a 10% chance in any given year during the construction period. The 10-year construction sediment load is equivalent to the load of sediment that would be generated by a 13 year ARI event with a 7.4% chance of occurring in any given year in the background scenario, i.e. it is equivalent to a slightly less frequent and less likely event.

Table 34 below shows the addition modelled sediment yield entering the receiving environments and places this in the context of the overall background annual sediment load for the same receiving environments. This is presented as the mean annual sediment yield; however, we note that, as illustrated in Table 31 above, that for some of the 5 construction years, the sediment yields are significantly less than the mean.

Table 34: Mean annual sediment loads in the Mahurangi and Pūhoi Catchments for a 5 year construction programme

Catchment	Background mean annual sediment load (t/year)	Additional mean annual sediment load (t/year)	Increase (%)
Mahurangi River catchment	12193	1553	12.7%
Mahurangi Harbour catchment	45931	1553	3.4%
Pūhoi River catchment	18311	1261	6.9%

7.8 Stream sediment transport and deposition

WAFR 3 also assesses the average annual fraction of sediment generated in the catchment that is delivered to the coast (FSDC). This assessment is to allow an understanding of how much of the sediment from the Project earthworks could enter the estuaries and how much may be retained in the rivers and streams. Monitoring in the Mahurangi catchment (Stroud and Copper 1997) was used to calculate the FSDCs. We have adopted the following FSDCs for the assessment.

In relation to catchment background loads:

- For the estuary modelling, the FSDCs as modelled in the BNZ study apply, because these fractions are implicit in the modelled loads entering the Mahurangi estuary, which were calibrated against measurements. For those catchments not modelled in BNZ, and FSDC was applied based on similarity to modelled catchments; and
- For the stream assessment, the sediment load remaining in the stream is the background load scaled with the FSDC factors.

In relation to the FASY:

- For the estuary modelling, it is reasonable to adopt a conservative assumption consistent with a steady-state conceptual model of these catchments (and the finer particle size distribution (PSD) of earthworks generated sediments), i.e. all sediment is delivered to the estuary (FSDC of 1). By applying this assumption we allow for no reduction in the suspended sediment concentrations (TSS) in the freshwater environment between the point of their discharge from the Project to where the estuarine system begins; and
- For the stream assessments, adopting the same FSDC as suggested for the estuary modelling implies no deposition of earthworks generated sediment in the stream. An alternative and more conservation approach is to assume construction sediment is deposited at the same rate as background loads.

We have also used predicted stream flow velocities, shear stress and visual assessments to inform our understanding of sediment transport in the watercourses.

Understanding the transportation and deposition of sediment within streams is also useful in assessing the effects of change in water quality on colour, clarity and amenity values and the effects of existing users throughout the catchments.

The transportation and deposition of sediment within streams is useful in understanding the duration of effects.

WAFR 3 estimates the fraction of sediment delivered to the coast (FSDC). For the Mahurangi River system the FSDC is estimated to be 0.48, meaning that in the background situation 52% of sediment discharged to the river would be expected to be deposited in the river network and floodplain.

For the Pūhoi River (and Hikauae Creek) the FSDC is assumed to be 0.5, meaning that 50% of the background sediment discharged to the river would be expected to be deposited in the river network and floodplain.

Table 35 and Table 36 provide results of the sediment deposition for the assessment, in the 2 year ARI event.

Table 35: Background 2 year ARI event background sediment loads. FSDC applied to loads

Site ID	Fraction sediment delivered coast (FSDC)	Catchment sediment load (t)	Sediment load deposited upstream of site (t)	Sediment load discharged downstream of site (t)
AC-FHQ	0.48	471	245	226
MW	0.48	2700	1404	1296
Mahurangi River Mouth	0.48	5213	2711	2502
P10	0.5	790	395	395
Pūhoi River Mouth	0.5	7516	3758	3758

By way of explanation of the above table, in the background scenario, WAFR 3 predicts a total sediment load of 7,516 t within the Pūhoi Catchment. Of this, 3,758 t is expected to discharge to the marine environment, with the remaining 3,758 t being deposited within the river network and floodplain.

Of the sediment deposited in the Pūhoi River network, 395 t is expected to be deposited upstream of the site P10 or the Hikauae Creek (refer to Figure 8).

Table 36: Freshwater Assessment. Two year ARI sediment yield with the same FSDC applied to background load

Site ID	Fraction sediment delivered coast (FSDC)	Catchment sediment load (t)	Sediment load deposited upstream of site (t)	Sediment load discharged downstream of Site (t)	Additional sediment load associated with the Project
AC-FHQ	0.48	736	383	353	266
MW	0.48	3024	1572	1452	324
Mahurangi River Mouth	0.48	5537	2879	2658	324
P10	0.5	1086	543	543	296
Pūhoi River Mouth	0.5	7812	3906	3906	296

By way of explanation of the above table, we predict a sediment load of 7,812 t in the Pūhoi Catchment. Of this, 3,906 t is expected to be discharged to the marine environment, with the remaining 3,906 t being deposited in the river network and floodplain.

Of the 3,906 t deposited in the Pūhoi River network, 543 t is expected to be deposited upstream of the site P10. This assessment assumes that construction sediment yield will be deposited at the same rate as the background sediment. The sediment predicted to be deposited in the Pūhoi Catchment is expected to increase by 37% upstream of P10 and by 4% for the whole river catchment.

We consider the analysis provided in Table 36 to be conservative. For the Marine Ecology Assessment Report, we have assumed that all of the construction sediment load will be discharged to the coastal environment, because the construction sediment will have a finer particle size than the background sediment.

This assumption is consistent with a 'steady state' conceptual model of these catchments in which the rivers and streams are not aggrading (i.e. accumulating sediment) over the long-term (upstream of tidal reaches). In reality, deposition and sediment delivery are likely to vary with storm event size and cycles of bank accretion and erosion, with a long-term balance. However, there have been no formal studies to investigate these processes in these catchments.

We have also assessed stream morphology; the streams have soft bottoms in many places. In some locations bedrock is exposed. Therefore the streams do not appear to be aggrading, and therefore over time most sediment deposited in the channels will be re-worked and transported to the estuaries. The rate of sediment transport and deposition will vary from event to event.

7.9 Coastal sediment transport and deposition

eCoast were engaged by the FNA to develop coastal process models of the Pūhoi and Mahurangi estuaries (eCoast 2013) which is referenced in WAFR 5. The inputs to the estuary models are the flow hydrographs and associated TSS concentrations calculated from the GLEAMS sediment yield modelling. The estuary models predict sediment transportation and deposition during the 10 year ARI rainfall event and 50 year ARI rainfall event sediment yield events which, while a lower probability, are considered a higher risk than the 2 year ARI rainfall event.

WAFR 5 draws together the background sediment loads, the FASY and event hydrographs, and models the hydrodynamic process within the coastal environment to make predictions about sediment transport and deposition.

Figure 30 below illustrates how the background sediment modelling (as outlined in WAFR 3), the construction sediment modelling (as outlined in WAFR 5, the event flows (hydrographs) fed into the coastal processes model (as outlined in WAFR 5). These are then used within the model to enable us to make estimates of sediment transport and deposition in the receiving environment.

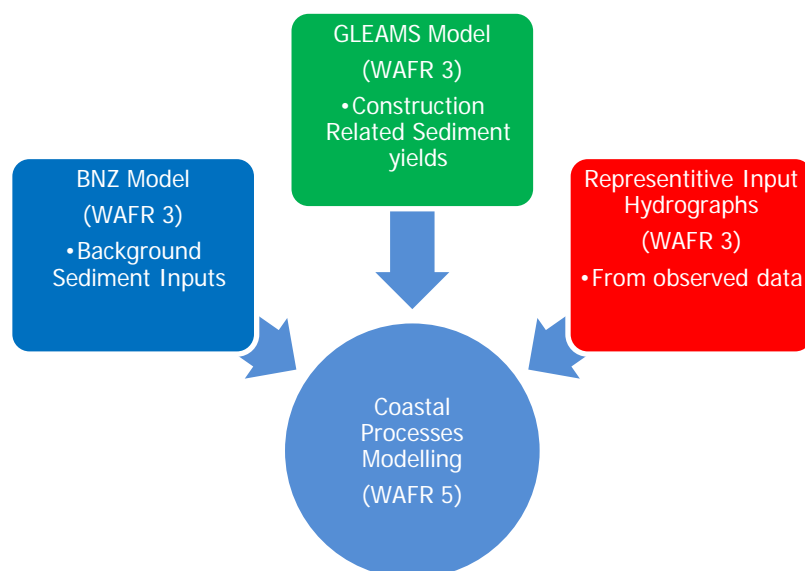


Figure 30: Input sediment and flows to the estuary models (Further North, 2013)

We have used the coastal modelling to predict the quantity of sediment retained within the estuaries and the quantity of sediment transported into the open sea, beyond the heads of the harbours. We also use these estimates of sediment transport and deposition to understand any potential impacts of the project on estuary infilling.

The model predicts the change in TSS in the estuary after events and the duration of this change. This information is useful in understanding the impact of the Project on change in colour and clarity.

The modelling provides information on the flushing rate of the marine waters within the estuaries. We have used this information to understand the duration of potential changes in marine water quality.

WAFR 5, documents the investigations undertaken to assess the likely coastal environment locations and magnitude of changes in sediment deposition depths and TSS concentrations. This assessment considers the effect of the 10 and 50 year ARI rainfall events coinciding with the maximum open area of earthworks during the construction of the Project.

This investigation includes an assessment of the probability of these impacts occurring, as well as the uncertainties around the findings.

Figure 31 below presents plots of the maximum earthwork areas TSS concentration estimated during the 10-year ARI and 50-year ARI background event. These results show that the high TSS concentrations are largely confined to the upper reaches of the harbour. The high TSS concentrations are clearly seen in the river channels at low tide where the velocities of water flow carry the sediment further out into the estuary where TSS concentrations dissipate.

We have used the estimate of the additional sediment yield generated during the construction period, and the modelling undertaken in the Mahurangi and Pūhoi coastal environments (WAFR 5) to assess the locations of predicted sediment deposition. This assessment is contained within the Marine Ecology Assessment Report.

For the Pūhoi, we have used an estimate of 70% of sediment remaining in the estuary (WAFR 5). This estimate based on the modelling of the sediment remaining in the Pūhoi after 3 days, following the 10 year ARI event. This is likely to be a conservative long-term estimate as some re-suspension and loss of sediment from the estuary can be expected over time. Over the whole 5 year construction period, we estimate 5mm of increased sediment depth in the Mahurangi Estuary and 2mm in the Pūhoi as shown in Table 37.

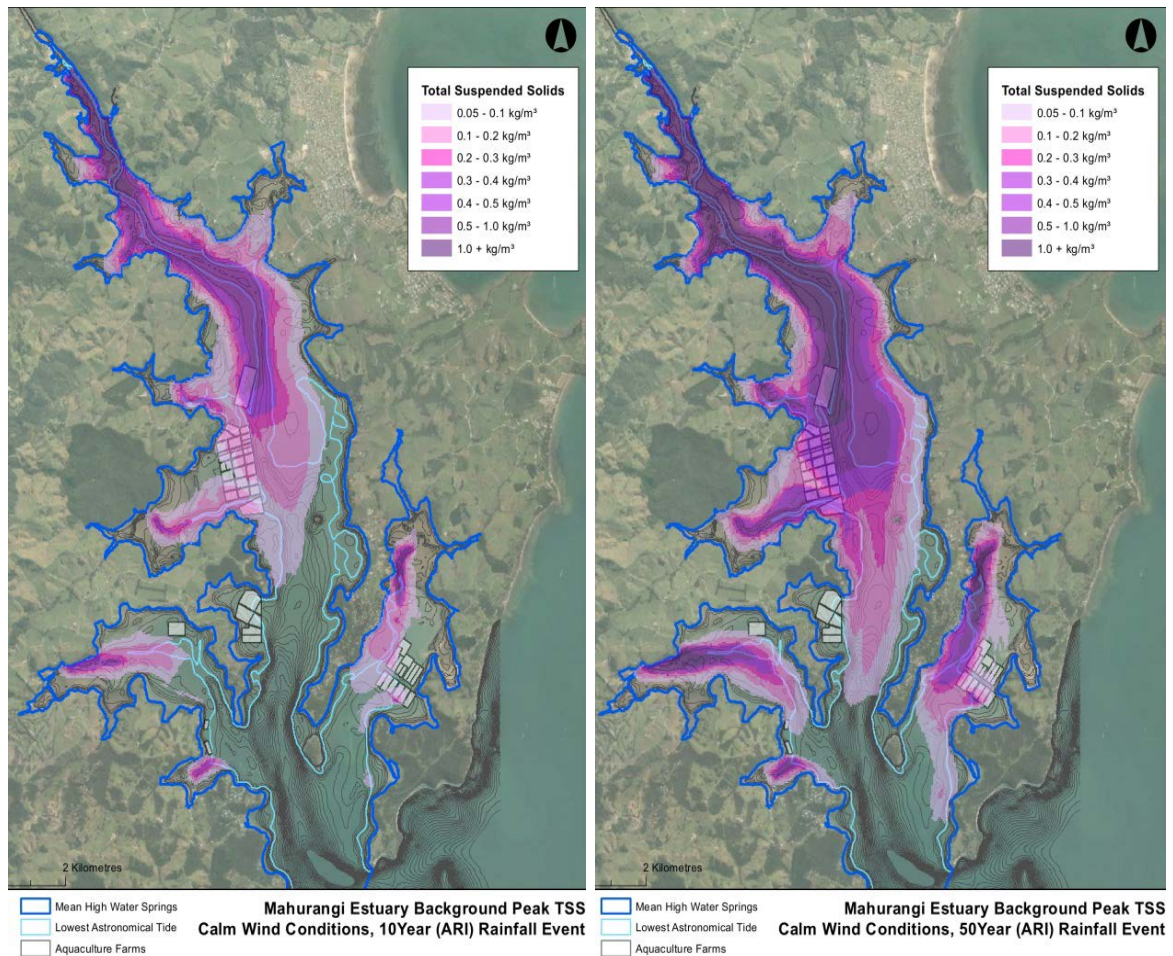


Figure 31: Modelled Background maximum area total suspended sediment load in the Mahurangi estuary in the 10 and 50 year sediment yield scenarios, calm wind conditions.

Table 37: Estimated total additional sediment deposition in the estuaries over the five year construction period

Estuary	Deposition area (ha)	Total increase in sediment load over 5 years (t)	Sediment remaining in Harbour. (%)	Average additional depth of sediment over the 'deposition area' (mm)
Mahurangi	100	7767	80%	5
Pūhoi	150	6307	70%	2

7.10 Construction nutrient loads

WAFR 3 has calculated changes in nutrient loads arising from nutrients bound in sediment entering the watercourses. The nutrient concentrations in sediment will reflect the background concentrations found in these catchments for the land-uses that are being disturbed. We would not expect that the Project will alter the concentration of nutrients in soils.

Assessing the change in nutrient load will help to understand whether the Project is likely to change the quality of water in relation to nutrient guidelines for ecosystem health. It is also useful to understand whether we would predict the changes in nutrient loads to cause changes to algal growth. A nuisance algal growth can have effects on scums and foams, recreational and amenity values.

The Pūhoi and Mahurangi Catchments contain slightly elevated concentrations of some nutrients as outlined in the WAFR 4.

Phosphorus in freshwater is more often elevated however some forms of nitrogen are also slightly elevated at times. Phosphorus is also slightly elevated in the data gathered by Auckland Council in the Mahurangi Estuary. The estuary is considered to be nitrogen-limited, that is the low concentrations of nitrogen provide a control which limits the growth of algae and other plants.

WAFR 3 calculated changes in nutrient loads and concentrations. This work drew on modelled ratios for sediment-P and sediment-N from the BNZ modelling work (Stroud et al. 1997). The estimates are only for the Mahurangi Catchment, where this modelling was undertaken.

The assessment of nutrient loads and concentrations for the Project has been limited to particulate forms of the nutrients modelled in the BNZ study as these are related to the sediments modelled in that study. While it is reasonable to assume that loads of sediment-N and sediment-P are strongly related to loads of sediment, this is not the case for soluble forms (Stroud et al. 1997).

The sediment-N and sediment-P released with sediment from the Project, relates to the naturally occurring nutrients in the soils.

On a Mahurangi Catchment-wide basis we assess that the Project will increase the total load of phosphorus by 7% and nitrogen by 8% (see Table 38). The background estimates are based on the BNZ model (Stroud et al. 1997).

The increase in total nutrients is calculated by the ratio of the sediment-N and sediment-P associated with the predicted increase in TSS with the project. In other words, we applied a scaling factor to the increased nutrient levels in proportion to the increase in sediment.

Table 38: Total N and Total P loads and concentrations at Mahurangi River mouth.

Nutrient	Background load (t/year)	Background and construction sediment load (t/year)	Background concentration (mg/L)	Background and construction concentration (mg/L)	Increase (%)
Nitrogen	121.6	132	5	5.4	8
Phosphorus	17.7	19	0.7	0.8	7

We expect sediment-N and sediment-P to be released in pulses with sediment during rainfall events. NIWA has calculated concentrations for sediment-N and sediment-P at the MW and AC-FHQ sites. These sites show larger relative increases in nutrient concentrations, compared to the mouth of the Mahurangi, because the construction footprint makes up a larger proportion of these catchments.

We have not undertaken modelling to calculate the increase in nutrients in the Pūhoi Catchment. There is inadequate existing data to base estimates on for this catchment. However, we consider that similar levels of nutrients are likely to be found in the soils in the Pūhoi and Mahurangi Catchments, because they have similar geology, climate and land-use, and that like the Mahurangi, increases in sediment-P and sediment-N will be related to increases in sediment loads. Our assessment of the construction nutrient loads is included within Section 9 of this Report.

7.11 Other contaminants

Other discharges during the construction works may include:

- Discharges of sediment pond treatment chemicals that may affect pH or have a direct effect (e.g. Aluminium in Alum);
- Clean water discharges from cut off drains and diversions;
- Dewatering water from deeper cut earthworks; and
- Accidental discharges such as spills of fuels, oils, cement etc.

Our method for assessing the potential effects of these contaminants is based on the experience of similar projects.

Contaminants such as traces residues of pesticides may be present in existing soils. The Project will not alter the concentrations of these contaminants, but soils that contain these contaminants may be disturbed during the Project construction. The method for assessing the effects of these contaminants is detailed within the Contaminated Land Assessment Report.

Assessing the effect of the Project on the release of contaminants that are currently attached to soils is useful to understand whether the disturbance of these soils could cause effects on ecosystems values and existing users of fresh and marine waters.

The Contaminated Land Assessment Report has identified contaminant concentrations in soil that may pose an unacceptable risk to human health and the environment. These are located on four land parcels within the proposed designation area and relate to activities such as automotive workshops and sheep dips that have historically been operating.

The Contaminated Land Assessment Report indicated that only 90m³ of potentially contaminated soil has been identified to date and recommended, given that concentrations of these contaminants are likely to be confined to a relatively small area, that contaminated soil is removed and disposed at an appropriately licenced facility. This approach will mean that any effects on human health or the environment will be avoided.

Project works will include a wide variety of machinery that may require refuelling onsite, hence there may be fuel and oils stored onsite. In addition building materials including cement and bitumen can have impacts if spilt into the freshwater environment. We consider the risk of accidental spills of hazardous substances and other contaminants can be managed through good site practices. Section 4.8 of this Report provides further detail on these aspects of site management.

8. Monitoring

We recommend that the water quality sampling and an adaptive monitoring programme be carried out during the construction phase of the Project.

Sampling data will be used to understand the quantum of sediment yields from the construction activity and the effect of sediment reaching the receiving environment, which will then be used to allow for adjustment of the construction water management measures and construction activity onsite.

The key components of the adaptive monitoring will include:

- Receiving environment visual assessments;
- Weather forecasting;
- On site monitoring of devices;
- Flocculation monitoring;
- Quantitative water quality and flow monitoring; and
- Habitat monitoring.

The results of the adaptive monitoring programme results will be used to identify future risks to ecology based on pre-determined trigger levels. These triggers are not effects triggers but identify a point at which investigation, intervention and continuous improvement opportunities are to be considered.

We recommend that an adaptive monitoring programme be developed for the Project as illustrated in Figure 33. The focus of this monitoring programme is the management of sediment yield from the Project. Measures required to manage sediment will also capture sediment bound contaminants, such as nutrients and pesticides.

This monitoring programme will involve ongoing site monitoring to check that the proposed water management measures have been installed correctly and that methodologies are being followed and are functioning effectively throughout the duration of the works.

Monitoring results that eventuate, as defined below, will also be used to identify future risks to ecology based on pre-determined trigger levels. These triggers are not effects triggers but will identify a potential effects point at which investigation and continuous improvement opportunities should be considered by the construction team.

Water management measures and methodologies may be identified as requiring modification or improvement, including those causing raised levels of sedimentation based on the pre-set trigger levels.

The monitoring programme will include risk assessment to determine what further measures are required to reduce sediment yield. The adaptive monitoring will include a continual feedback loop until it has been verified that the implemented responses have been successful in minimising sediment yields from the Project.

8.1 Qualitative monitoring

8.1.1 Receiving environment - On-site visual assessments

The Construction Manager will have an important role, to ensure that visual assessments of the receiving environment are maintained regularly throughout the works period with particular attention paid before, during and after periods of rainfall.

In the context of visual assessment the receiving environment is defined as the immediate receiving environment adjacent to the area of works however, the wider coastal environment will also be subject to visual inspections.

Any noticeable change in water clarity from the water clarity prior to the rainfall event, or the water clarity upstream of the site of works, as a result of the earthworks activity will result in a review of the ESC measures and practices and additional measures will be implemented and changes made as necessary under the adaptive management procedures.

8.1.2 Weather forecasting during Project implementation

Weather forecast monitoring will form an important part of the Project implementation to ensure that higher risk activities as defined in Section 5 of this Report, such as those associated with the stream diversions, will only occur during a suitable fine weather window.

We note the extensive use of weather forecasting that now occurs with most land-disturbing activities and the value that it provides in informing contractors of upcoming weather systems.

As an example, on the Long Bay project this forecasting has proven to be a successful management tool in avoiding high risk stream works over wetter periods of the year. It also provides guidance for activities such as when temporary stabilisation must occur.

8.1.3 On-site monitoring of water management devices

Monitoring of onsite devices is referred to as 'Devices Monitoring' and refers to environmental compliance for the Project during the construction period. It is based upon the appropriate installation, location, maintenance, and monitoring of control devices. It is important that within the context of monitoring, the devices are not restricted to physical structures and will also include work practices and methodologies.

The purpose of the Devices Monitoring is to check that all practices, control measures and devices are constructed, operated and maintained so they remain fully effective at all times.

Devices monitoring is aimed at the early detection of activities or problems that have the potential to result in an adverse environmental effect. The device monitoring will act as an immediate trigger, and if required, together with scheduled ecological monitoring, for more detailed 'trigger event' monitoring.

The frequency of the devices monitoring will vary throughout the year and will reflect areas of changing activity and risk along the Project. During the construction period the monitoring will be

undertaken daily and more frequently during heavy rainfall as defined by 25mm within a 24 hour period or 15mm within a one hour period.

These inspections will be recorded using a weekly checklist as provided in the NZTA Draft Standard and as included within Appendix B of this Report. The inspections will include qualitative monitoring of the following:

- The integrity and effectiveness of all construction related water management devices;
- Construction activities onsite upstream of the ESC device;
- General site conditions and other land disturbing activities occurring within the catchment; and
- General status of the immediate receiving environment.

To ensure a full understanding of the area of works is available, prior to construction commencing, photographs will be taken in the vicinity of proposed discharge outlet points and any streams in the vicinity of the works.

These records will illustrate the visual state of the receiving environment at and within the vicinity of the discharge point. This photographic record will be compiled into a log book and will allow a visual comparison of before, during and at completion of the construction of the Project.

The monitoring data will help to determine whether any further action is necessary. Where issues with the integrity and/or effectiveness of the ESC devices and/or methodologies are observed these shall be rectified immediately.

8.1.4 Flocculation monitoring

A core part of flocculation management is monitoring in order to check that the systems are all working as anticipated and to provide information to facilitate management of the flocculation systems. We have demonstrated that there are chemical flocculants available that are successful in achieving sediment settlement of the soil types that will be encountered on the Project. These are discussed in Section 6.1.8 of this Report and also WAFR 2.

We recommend monitoring should be undertaken based upon checking the treated detention device discharge and receiving environment pH levels at weekly intervals and during rain events of greater than 25mm within a 24 hour period.

We note that some of the flocculants tested as detailed within WAFR 2 have no effect on pH levels and if such chemicals are used on this project then there will be no requirement to monitor discharge pH levels.

8.2 Quantitative monitoring

In addition to the on-site monitoring of water management devices as detailed above, quantitative monitoring will be undertaken on the Project. The objective of this monitoring programme is to provide data for an array of rainstorms of different magnitudes and intensities, as well as providing information on the total sediment discharge from the site during the earthworks period.

8.2.1 Automatic rainfall monitoring

We recommend rainfall monitoring using existing rain gauges within the catchment or through the installation of a new automated rain gauge within the Project site. This rain gauge will be based on a telemetry system whereby rainfall records (depths and intensities) can be viewed remotely, alarms triggers set and construction staff alerted through various rainfall trigger points.

We highlight the implementation of this as part of the Long Bay development where rainfall is automatically recorded. This data is constantly monitored and when specific trigger points are breached a series of site actions occur.

8.2.2 Flow monitoring

We recommend continuous discharge flow monitoring on the outflows from two selected sediment retention ponds that are considered to best represent a high risk location of the earthworks on the Project. The flow monitoring device will be moved as the Project progresses. A standard 'V' notch weir will be installed in the outflow channels and the water depth at each weir will be measured using a pressure transducer. Flows will be recorded electronically. These systems are powered via solar units.

8.2.3 Sediment discharge monitoring

We recommend automatic continuous sediment sampling to measure the suspended solids concentration through storm events from the outfalls. This will occur in the same two SRPs subject to flow measurement discussed in Section 8.2.2 of this Report.

Sediment monitoring will be undertaken using an automatic water sampler at the flow monitoring site to take samples spaced at volume intervals that will be selected to ensure that as close as practicable to the total stormwater discharge from a major rainstorm event is monitored. The suspended solids concentrations of the samples will be tested to determine the effectiveness of the SRP and chemical flocculant dosing system.

The sediment monitoring programme has the aim of providing outflow sediment yield data which, along with the analysis of sediment construction yields through manual sampling of inflows, will assist with determination of any effects that may result downstream.

8.2.4 Additional manual monitoring

Manual monitoring of outflow associated with a selection of SRPs will occur where practicable. This manual monitoring supplements the automatic sampling and allows for comparative analysis between samples. In addition monitoring of the receiving environment through manual sampling, both upstream and downstream of discharges, will occur where practicable.

8.2.5 Data collection

An example of the nature of the information collected is shown in Figure 32 of this Report. This figure illustrates the discharge water levels leaving a SRP at Long Bay (Blue Line) and also the corresponding cumulative rainfall (Green Line).

From a sampling perspective we will collect samples on a flow proportional basis throughout the outflow hydrograph which will illustrate the water quality throughout the rain event.

This sample collection method enables identification of periods when water quality may not be satisfactory. This information will help construction staff to specifically target these periods and if necessary adjust the ESC measures and practices onsite.

As an example, if water quality shows a decline at the peak of the hydrograph, this decline could indicate a problem with the chemical flocculation dosing system at that time and enable 'fine tuning' of that system.

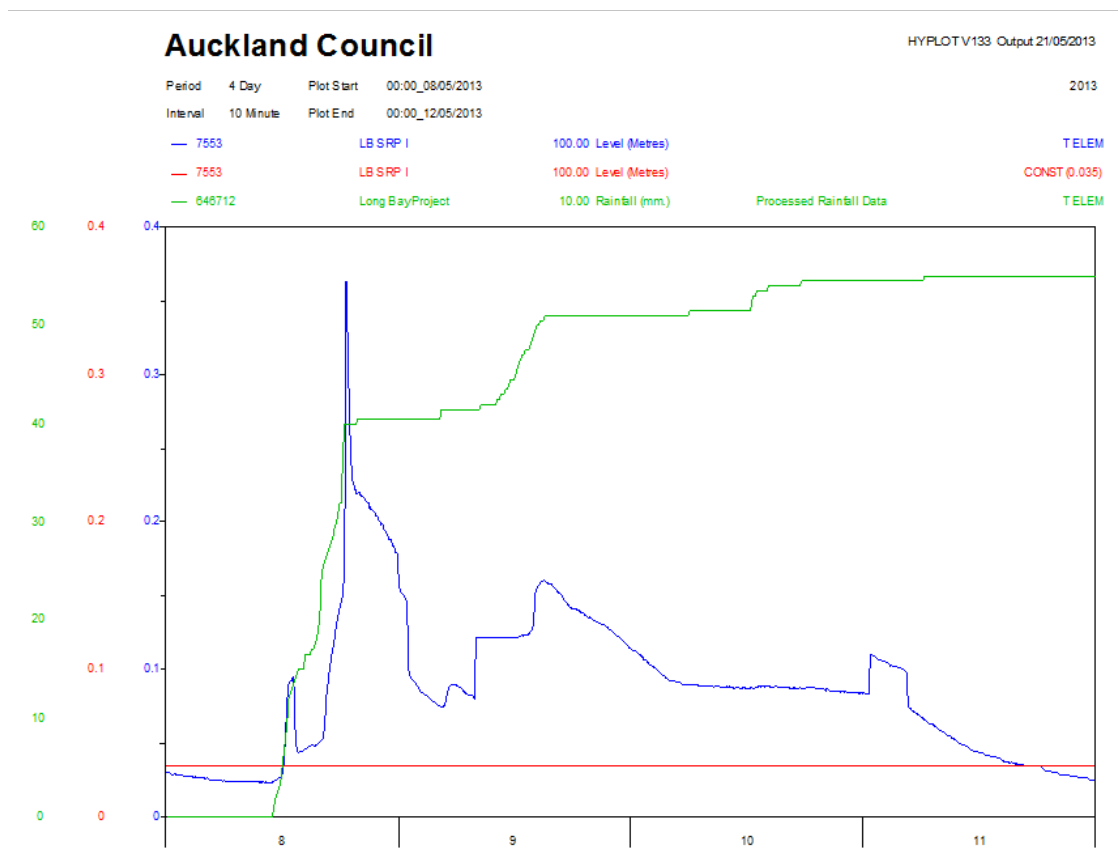


Figure 32: SRP outflow hydrograph for a sample rain event at Long Bay

8.2.6 Pre and post-earthworks season earthworks monitoring

Prior to the start of each earthworks season activity, and again at the completion of the earthworks season activity, surveys will be undertaken in the freshwater and marine habitats in order to establish a robust baseline. These surveys will be undertaken at a similar time of year to ensure comparative analysis can occur and will include freshwater, brackish and marine sampling. This monitoring will validate the ESC approach taken.

Freshwater surveys will occur at selected newly established sites. Both macroinvertebrates and fish will be monitored.

Marine surveys will be focused on both the Pūhoi and Mahurangi coastal habitats. Monitoring will have to consider other activities occurring in catchment that coincide with the Project. Particular emphasis will be given to the potential growth of Warkworth that may occur during the construction period timing.

8.3 Freshwater and coastal monitoring

The purpose of the freshwater and coastal monitoring is to identify and quantify potential adverse effects on the freshwater and marine environments arising from construction runoff and coincident activities.

The monitoring data will inform appropriate management responses to avoid, remedy or mitigate adverse effects.

Triggered monitoring results from activities or events that may trigger:

- Greater than 25mm of rainfall over any a 24 hour period;
- Greater than 15mm of rainfall with an hour period;
- Spillage/accident reports that cause a discharge of sediment or contaminants to the aquatic environment; or
- Obvious degradation of the receiving environment immediately downstream of the SRPs such as accumulation of sediment, conspicuous oil/grease, scums/foams, floatable matter, fish kills, discolouration of water or significantly increased growth of nuisance algae.

8.3.1 Level one monitoring and management response to trigger events

In the event of a trigger as described above, and within a 48 hour period of the trigger, the ESC management will be investigated to determine whether there has been a discharge from the devices. If there has been a discharge, the receiving environments will be investigated.

The key determination of this initial response is:

- to determine if an area of deposition has occurred over an area comprising greater than 10% of the freshwater environment of the most upstream SRP discharge point; and
- to determine if any earthworks sediment is deposited within the coastal environment and if so the extent of such deposition.

In the event of a Level One Response the consent holder will:

- Inspect the earthworks site, all erosion and sediment controls and associated management procedures to identify any problems or activities likely to have contributed to increased sediment discharge to the receiving environment;
- Take manual samples of discharges as necessary; and
- Remedy any identified problems, and implement any further controls on activities that are likely to contribute to increased sediment discharge.

8.3.2 Level two freshwater monitoring and management response

If freshly deposited sediment originating from the earthworks is detected within the freshwater environment, the depth and extent of deposition shall be estimated. If the area of deposition at a depth of greater than 5mm is estimated to occur over an area comprising greater than 10% of the receiving environment downstream from the SRP discharge, then a repeat of the pre earthworks ecological monitoring requirements will occur.

8.3.3 Level two marine monitoring and management response

If freshly deposited, potentially earthworks derived sediment is detected, sediment deposition depth will be measured by cutting a vertical face through the deposit with a rule. If at the time of the first inspection (i.e. within 48 hours), earthworks derived sediment has been deposited to a depth of greater than or equal to 5mm over a continuous area of 1000 m² (or greater), or a discontinuous area of 1000 m² within an area of 3000 m², the triggered sediment depth and extent monitoring above shall be repeated three days after the first triggered inspection.

If the average deposition depth exceeds the above criteria at three days after the first inspection, an ecological survey shall be triggered and will be undertaken within the next 48 hours.

8.3.4 Accidental spillage monitoring and management response

Accidental spillage of contaminants or sediment into the aquatic environment, and/or the detection of obvious degradation of the aquatic habitat downstream of the pond discharge point, will trigger ecological surveys of the habitat affected within 48 hours. Appropriate measures will be implemented to remedy or mitigate any adverse effects identified.

8.4 Monitoring response to indicators of effects

If as a result of the monitoring programme, effects on the receiving environments are detected, the following steps should be undertaken:

- In the first instance, investigate a possible (cause-effect) association with the Project;
- Should this investigation prove to establish linkages between the adverse effect and on-site practices, then investigate alterations to the operational methods (including modifications to environmental control measures and methodologies) as a first order response; and
- Assess the effectiveness of the alterations in operational methods by conducting further monitoring to alleviate/avoid adverse effects on the environment.

Factors to be considered in the decision chain relating to the above would include the need for, and nature of, any remedial action.

The most likely cause of an effect would be the incorrect installation of devices or sub-optimal performance of the measures and methodologies implemented.

We consider that the implementation of the measures and methodologies as detailed within the Report will ensure that the possibility of such an occurrence is minimised. Further the adaptive

monitoring programme will provide a 'check and balance' and will provide the opportunity for continuous improvement as necessary throughout the construction period. The adaptive monitoring programme is illustrated in Figure 33 below.

Both the Freshwater and Marine Ecology Assessment Reports endorse this monitoring approach.

Adaptive Monitoring Programme

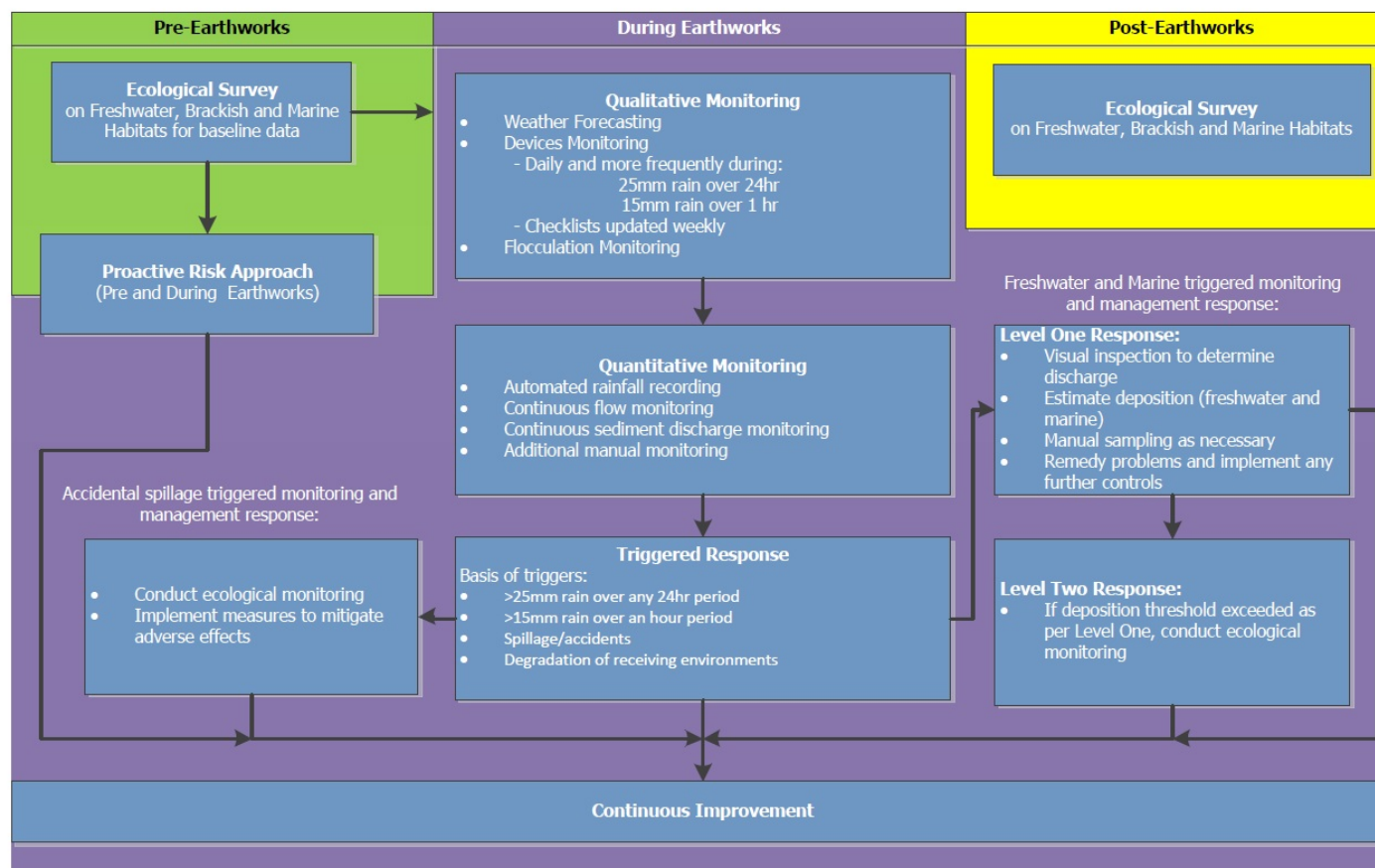


Figure 33: Process of adaptive monitoring for Project (Further North, 2013)

9. Assessment of construction effects

Construction related sediment yield effects

We have assessed the overall environmental effects of construction related water discharges including those associated with sediment yields. Our assessment considered the approach taken to construction water management, the use of Focus Areas to determine sediment yields for the entire Project and the linkages to the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

We have considered the construction methodologies and sediment yields and assess the effects of the overall construction related water management as minor.

Water quality effects assessment

The water quality assessment was focused on effects on:

- Aesthetics and odour;
- Human health; and
- Water users.

We have undertaken this assessment assuming implementation of proposed erosion and sediment control measures that meet the design and performance assumptions, as defined in of this Report.

The effects on ecosystems are discussed in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

We have undertaken an assessment of the effects of the construction water management aspects of the Project. The specific criteria from the relevant statutory documents are outlined below, and for ease of reference the assessment process and response is also included below.

The assessment is based upon the effects of construction related discharges and in particular those associated with sediment yields from land disturbing activities, including earthworks.

In addition to the assessment provided in this section, the effects of construction-related water discharges are assessed in the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report.

We recognise that a range of land-disturbing activities (including streamworks) will be undertaken as part of the Project and that these have numerous requirements under policy and planning documents. The detail of these planning documents is discussed within the AEE that supports this Project.

When considering these policy requirements several key items are of importance in terms of construction water management discharges, including:

- Proximity to permanent waterbodies, including the CMA;

- Values of the receiving environments adjacent to, or downstream of, the Project;
- Site topography;
- Areas of exposed soils or geotechnically unstable areas; and
- Loss of terrestrial and stream habitat that may occur as a result of the Project.

We have considered these items in full in developing this Report and they are reflected in the overall approach and the methodology we have taken. We note that the design and methodologies adopted within this Report are based on a Best Practical Option (BPO) approach. Developed and tested systems are employed to achieve the necessary outcomes.

This design and the associated methodologies reflect TP90 and also reflect experiences from other NZTA and development projects.

In particular we place emphasis on the success of the environmental management techniques employed at the Long Bay development, which have demonstrated the significant benefit of both structural and non-structural control measures.

Within this Report we have based our assessment on more detailed analysis undertaken within Focus Areas which have been assessed as representative of the whole Project.

We have also undertaken an analysis of specific activities, and for each of these we have provided an example from within the Project where a detailed methodology is developed and documented. To ensure we can assess the overall Project construction water management effects we have determined that the methodology is applicable to the remaining parts of the Project.

9.1 RMA Considerations

Section 104(1) of the RMA requires regard to be had to specific factors, subject to Part 2 of the RMA (Purposes and Principles). The purpose of the RMA is to promote the sustainable management of natural and physical resources.

Sustainable management means the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while:

- Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations and;
- Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; avoiding, remedying or mitigating any adverse effects of activities on the environment.

With reference to

Table 39 below, sections 105 and 107 of the RMA require regard to be had to additional matters associated with the discharge of contaminants.

9.2 Construction water management assessment

9.2.1 Criteria consideration

- i. Implementation of best practicable option (BPO).
- ii. Consideration of overall effects of sediment yield.
- iii. Consideration of proposed choice of approach, measures and methods employed and monitoring programmes.

9.2.2 Assessment against the ARP:SC

The ARP:SC was made operative in November 2001. The ARP:SC recognises that significant quantities of sediment are discharged from bare earth surfaces without appropriate erosion and sediment control. Such bare surfaces are created by land development or redevelopment activities that involve vegetation clearance and/or earthworks. These include land development for forestry or agricultural use, land contouring for urban development and road works and quarries. Resultant sediment discharge has been identified by Auckland Council as a major pollutant, by volume, of the waterways of the Auckland Region.

The statutory responsibilities of the Auckland Council include the control of the use of land for the purpose of the maintenance and enhancement of the quality of water in water bodies and coastal water and the control of discharges of contaminants into or onto water.

The ARP:SC addresses the issue of sediment discharge, and defines the mechanisms Auckland Council has chosen for avoiding, mitigating or remedying any adverse effect on the environment due to sediment discharge from bare earth surfaces.

The ARP:SC details specific objectives as follows:

- *Objective 5.1.1 states that 'To maintain or enhance the quality of water in waterbodies and coastal water'.*
- *Objective 5.1.2 states 'To sustain the mauri of water in waterbodies and coastal waters, ancestral lands, sites, waahi tapu and other taonga'.*
- *Objective 5.2.1 states that 'Land disturbance activities which may result in the generation and discharge of elevated levels of sediment will be required to employ methods which avoid, remedy or mitigate adverse effects on the quality of water in waterbodies and coastal waters'.*
- *Objective 5.2.2 states that 'Land disturbance activities which may result in the discharge of elevated levels of sediment into waterbodies and coastal waters shall be considered inappropriate where they will have a significant adverse effect on:-*
 - i. The qualities, elements and features which contribute to the natural character of areas of the coastal environment, (including the coastal marine area) wetlands, lakes and rivers and their margins; and which are identified in the Auckland Regional Policy*

Statement and the Auckland Regional Plan: Coastal as having outstanding or regionally significant ecological, landform, geological or landscape values.

- ii. Outstanding and regionally significant natural features and landscapes as identified in the Auckland Regional Policy Statement and the Auckland Regional Plan: Coastal.*
- iii. Areas of significant indigenous vegetation and significant habitats of indigenous fauna as identified in the Auckland Regional Policy Statement and the Auckland Regional Plan: Coastal as having international, national and regional significance.*
- iv. Areas of significance to Tangata Whenua as identified in the Auckland Regional Policy Statement and the Auckland Regional Plan: Coastal.*
- v. Areas identified by Tangata Whenua in accordance with Tikanga Māori as being of special spiritual, cultural and historical significance. Unless the adverse effects can be avoided, remedied or mitigated.*

With respect to the Project, the timing and duration of the works is considered appropriate and the conditions of consent recommended in this Report will effectively avoid, remedy or mitigate any actual or potential effects of the Project. The proposed staging and sequencing of works in addition to the open area limitations will ensure effects are managed accordingly. We consider that the activities of the Project are consistent with the above mentioned provisions of the ARP:SC.

9.2.3 ARP:SC matters to consider

In addition to the other statutory matters, for completeness we have focused on the matters within the ARP:SC that Auckland Council has restricted its discretion to. These matters are reported below for ease of reference and are considered relevant for both land-disturbing activities and vegetation removal activities.

(a) Techniques used to restrict or control sediment and the effects of sediment on water quality

Details and design of the ESC measures and methodologies have been documented within this Report. The nature of TP90 controls anticipates discharges (albeit with the majority of sediment removed within control measures).

We have proposed measures to reduce erosion and therefore reduce the sediment generating potential of the Project site. The measures include progressive stabilisation with vegetation and hard fill and controlling upper catchment 'cleanwater' by diverting it around the earthworked areas, which will limit contributing catchments to the sediment control devices and reduce runoff volumes.

The main sediment control device to be utilised is SRPs and innovative design including baffles and reverse slopes and treatment with chemical flocculant. As determined within Sections 7 of this Report, we consider sediment yields can be minimised onsite.

The final details of the ESC measures and methodologies will be detailed within CESCPS. This approach will allow for contractor innovation, value engineering and technologies to be incorporated.

As outlined within the Freshwater Ecology Assessment Report and the Marine Ecology Assessment Report, sediment yields have the potential to cause adverse effects to both freshwater and marine environments.

Yields from the sediment controls are likely to have a higher turbidity than that prior to rainfall events. This turbidity effect will only be evident during and immediately after rain events.

We have demonstrated through other projects, in particular the Long Bay development that with good site management the yields from sediment control devices can be mitigated to ensure that there are no unacceptable adverse effects on the receiving environment in terms of water quality or ecology.

In assessing the effects of the potential sediment yields, the risk of the sediment yields is balanced against the nature of the receiving environment and consequent risk in terms of potential impact.

The area and duration of the activity, as well as the time of the year when the activity will be undertaken, are also taken into account. We have demonstrated that ESC measures can be employed to reduce the overall risk by the use of ESCs designed in accordance with TP90, innovative practices, non-structural measures and progressive stabilisation of disturbed areas.

We have based sediment yield calculations on a conceptual construction programme which is centred on undertaking the earthworks during the traditional earthworks season from September to May.

Any works over the winter period are focused on working within the sandstone material which is assessed as having a lesser degree of erosion than the weathered material. We also confirm that activities such as streamworks will be undertaken during the summer months to avoid prolonged wet periods.

In view of these considerations and with the recommended conditions of consent we conclude that sediment yield will be minimised and that the adverse impacts of sediment upon the receiving environment will be minor. We note that in a 50 year ARI rain event, we consider the effects to be moderate however due to the low probability of such an event occurring within the construction period we assess the overall effects of the Project to be minor.

(b) The proportion of the catchment which is exposed

The earthworks activity involves a cumulative area of approximately 189 hectares (based on conceptual construction programme). Staging is proposed as outlined within the construction section of the AEE which outlines a conceptual staging and sequencing programme based on a 5 year construction period.

This conceptual construction staging and sequencing programme has been used to assess sediment yields from the Project as outlined within Section 7 of this Report. This assessment is in turn used within WAFR 5 and the Freshwater and Marine Ecology Assessment Reports.

Our assessment from this modelling exercise confirms that a maximum earthworks open area at any one time is important to ensure only minor effects are realised. This maximum earthworks

open area equates to 41ha within the areas classified as Hill Country and 21.5ha within the areas classified as Flat Country, within Mahurangi Catchment.

The Pūhoi Catchment is considered as Hill Country and in this regard is treated as a standalone area with respect to earthworks open area limitations. As such, the maximum earthworks open area in the Pūhoi Catchment is 41ha.

From a constructability perspective we have assessed that the construction programme as defined within the construction section of the AEE can be achieved. This programme includes the provision for spoil site locations and the associated construction activities, earthworks and sediment yields from these locations.

We also assess that irrespective of the spoil site volumes and associated areal extent, the sediment yield calculations are based on an overall 'open area limitation' which will apply to the Project, including the open earthworks area of spoil sites during construction.

We note the importance of the adaptive monitoring programme whereby water quality monitoring will inform the earthworks open area limitation and associated effects. This monitoring may lead to an increase in open earthworks areas over time however, it will be based on analysis of the water quality outcomes and associated assessment.

Overall, we consider the effects to be minor.

(c) The concentration and volume of any sediment that may be discharged

With respect to sediment yields from the Project, we note the following principles:

- The greater the area of site disturbance, the longer the area remains in a disturbed state before stabilisation and the greater the slope will all result in a greater potential sediment yield;
- Disturbed land has a greater runoff or sediment yield potential than vegetated surfaces; and
- The closer the site disturbance is to a receiving environment (watercourse, estuary, marine area), the greater the potential for impact.

The Project involves earthworks over a large area with staging and sequencing proposed. Discharges from the site will predominately be to the freshwater environment which eventually discharges into the coastal habitat.

We have assessed the sediment yields using both GLEAMS and USLE with similar yields calculated between the two methodologies. Consistency between these two models has provided a degree of confidence that the yields are appropriate and representative.

Extrapolation of the yields from the Focus Areas has enabled the full Project sediment yields to be calculated. This also allows consideration of sediment yield for the Pūhoi, Mahurangi Hills and Mahurangi Flat areas. Based on the construction programme we assess sediment yields for the 5 year construction programme as below:

- Mahurangi Hills 5466t

- Mahurangi Flat 2302t
- Pūhoi 6307t

The assumptions used in calculating the sediment yields during earthworks are outlined within WAFR 1. It is considered that the assumptions provide the necessary comparison for overall assessment and risk management purposes.

The significant benefit of assessing sediment yield is using an onsite comparative analysis which allows high sediment areas to be identified and controls and monitoring to be targeted at these areas. The assessment provides a 'closer' look at the site and begins to narrow the focus on what is expected to be the high sediment generating areas within the site.

As reported within WAFR 3 we note that the 5 year background sediment loads are as follows:

- Mahurangi Harbour Catchment 229,655t
- Mahurangi River Catchment 60,965t
- Pūhoi River catchment 91,555t

These background loads place the sediment yields from the Project into context, and illustrate a small percentage increase overall for the respective catchments.

We conclude that with the use of chemical treatment and in association with staging and monitoring, that while the site has the potential to discharge sediment this will be at a level where we consider the effects to be minor.

(d) The length of time for which bare earth surface is exposed

As demonstrated through the construction section of the AEE it is proposed that works will largely occur during the summer period with winter works restricted to working the harder sandstone material. Staging the works in this way is assessed as a best management practice and will assist with minimisation of sediment generation from the Project.

We also note that the construction programme is based on a 5 year programme which has been demonstrated as a practicable and achievable programme. We assess that the 5 year construction programme is the minimum duration which in itself reduces the risk of high intensity rainfall and as a result reduces the probability of high sediment generating rain events.

That is not to say that there is a zero chance of a high intensity rainfall, such as a 50 year ARI rain event, occurring within a 5 year period but rather that it reduces the risk such that the probability is low. This probability conclusion is further supported when considering that the maximum earthworks open area only exists for a short period of time based on the construction programme developed.

9.2.4 Streamworks activities

Within Chapter 7 of the ARP:ALW the following objectives and policies are relevant for the Project:

(a) Objectives

7.3.1 To maintain and enhance where practicable the natural characteristics of lakes and permanent rivers or streams in Auckland Region and to avoid, remedy, mitigate the effects of their modification by activities such as structures, disturbance, deposition, planting or reclamation and drainage and the diversion of surface.

7.3.2 To recognise and provide for structures in, on, under or over bed of lakes and permanent rivers or streams for regionally significant infrastructure where this comprises the best practicable option and is important for providing for the protection of the environment and for enabling people and communities to provide for their health and safety and their economic, social and cultural wellbeing.

The following general policies relating to the streamworks are considered relevant:

7.4.3 Activities for which resource consent is required in, on, under or over the bed of any lake or Permanent river or stream shall be considered appropriate where:

- (a) No reasonable or practicable alternative method or location of undertaking the activity exists outside of the lake or Permanent river or stream; or*
- (b) The use of an alternative method or location would have more significant adverse environmental effects than using the bed of the lake or Permanent river or stream; or*
- (c) The purpose for which the activity is undertaken cannot reasonably or practicably be accommodated by existing activities or development in, on, under or over the bed of the lake or Permanent river or stream; and*
- (d) Efficient use will be made of the bed of the lake or Permanent river or stream by using minimum area necessary for the activity, and*
- (e) Significant cumulative adverse effects of the activity on the bed of the lake or Permanent river or stream will be avoided; or*
- (f) Significant cumulative adverse effects of the activity on the beds of Permanent rivers and streams in Urban Areas are avoided, remedied or mitigated consistent with the Urban River and Stream Management Framework.*

We have considered the above objectives and policies in this assessment. We conclude that subject to the imposition of the recommended consent conditions, overall the Project streamwork activities are consistent with the relevant objectives and policies.

We consider it to be of critical importance that the conceptual methodology is appropriate in that all works are to be undertaken in a dry environment with full stream flows diverted around the works area. While this is proposed within the methodology, CESCPS will be established which will confirm the specific methodologies and approaches to be undertaken.

Overall we assess the effects of the streamworks construction activity as minor.

9.3 Aesthetics and odour

9.3.1 Criteria / consideration for the assessment

After reasonable mixing, the contaminant or water discharged shall not give rise to any of the following effects in the receiving waters (RMA s107):

- i. Conspicuous oil or grease films, scums or foams, or floatable or suspended materials
- ii. Any conspicuous change in the colour or visual clarity
- iii. Any emission of objectionable odour

9.3.2 Oil and Grease films

Oil and grease may be released in very small amounts due to accidental spills. Any conspicuous oil and grease films that develop would be temporary. We consider the risk can be managed by the CESCPS. With this management in place we consider the effect to be minor.

9.3.3 Scums and foams

During sampling undertaken in the catchment the Project team did not note any existing obvious films, scums or foams at the sample points. A potential cause of foams and scums is algal blooms. A number of factors contribute to algal blooms including, light, water temperature, flow and nutrient concentrations.

Increases in sediment-N and sediment-P loads are expected to occur related to the increase in sediment yield whereas the other factors are unlikely to be modified.

The water quality characterisation has indicated that periphyton (algal) growths are present in the watercourse during summer low flows. These were however only observed at a few locations such as the water treatment plant site (AC-WTP), and were not observed as being widespread or dense elsewhere.

Periphyton grow (or accrue) in waterbodies under optimum growing conditions but then can be removed by high flows in the streams. (Biggs 2000) We consider that with an accrual time of 12 days (measured at Mahurangi River at College), stream flows will regularly flush periphyton from these rivers, and therefore any growths are likely to be temporary.

Increased TSS concentrations will potentially increase the loads of inorganic particulate phosphorus to the estuaries and while particulate phosphorus can disassociate/transform to dissolved forms of phosphorus the risk of impacts is considered low given the estuaries are N limited and much of the inorganic particulate material is likely to be removed from suspension and eventually buried.

In the absence of strong oxygen stratification of the estuaries as discussed in the WAFR 4, we consider buried P loads are unlikely to be reprocessed into the water column. Given these estuaries very rarely stratify, and if ever are only very short-lived for some parts of the Mahurangi Estuary, but never in the Pūhoi Estuary, the potential for increased sediment flux of dissolved phosphorus to the water column above background appears very low. We note that both estuaries have

extensive intertidal areas with tidal ranges of up to 2.9 m. During field work, temperatures were recorded up to 24 °C, and at most 0.5 °C difference in temperatures from surface to bottom with a strong diurnal signature (eCoast 2013).

Elevated TSS loads will potentially increase loads of particulate nitrogen but this is assessed as having only minor fractions of dissolved organic and inorganic nitrogen. Again, biogeochemical processes such as nitrification (conversion of ammonium to nitrate) and denitrification (conversion of nitrate to nitrogen gas) could potentially make this additional material available to the water column although the flux of materials from estuarine sediments to the water column via denitrification is considered low given this process occurs under anaerobic conditions.

Elevated loads of ammonium being associated with the Project are not considered significant given that organic matter will be managed and removed from site and topsoil will generally be stockpiled for reuse in landscaping. This suggests that additional loads of nitrate to the water column of these estuaries is not likely to cause adverse effects.

We consider that the receiving environment is not likely to develop nuisance algal growths as a result of the predicted loads of sediment N and sediment P.

9.3.4 Floatable or suspended material

The release of small quantities of floatable materials (in particular litter) may occur during construction. Litter, in particular plastics and their persistence in the marine environment makes them problematic. We consider the risk of conspicuous floatable or suspended material can be managed by the CESCps with this management in place we consider the effect to be minor.

9.3.5 Water colour and clarity

The predicted increase in sediment yield during rain events may result in a change in water colour and clarity. Existing data indicates that clarity is currently low.

The geology of the catchment is the source of the water colour, which can be described as bright 'yellowish-green' in the upper estuary (Davies-Colley et al. 2009). The sediment yield from the construction areas will be of fine clays and silts and may contribute to changes in colour. Conspicuous changes in colour and clarity in the rivers will be temporary and occur during and post storm events. If higher levels of TSS result, this will coincide largely with the natural change in colour and clarity that will occur during storm events. There is estimated to be a lag of between 24 – 48 hours, when the sediment ponds continue to discharge stormwater once streams have returned to baseflow.

A study of the optical clarity of the Mahurangi Estuary, (Davies-Colley, et al 2009), suggested an increase greater than 25% in TSS as a threshold for an unacceptable change in clarity in the Mahurangi Estuary. The Pūhoi Estuary does not have a water quality monitoring programme and therefore does not have data available for comparison. However the Pūhoi estuary has a similar catchment geology, land-use and flushing time as that of the Mahurangi Estuary. For the purposes of this assessment we have considered it appropriate to assume the same TSS threshold for the Pūhoi Estuary.

In all events, the post-treatment increase in TSS concentrations is assessed to be less than the 25% threshold in the estuaries. In the short 5 year construction scenario the increase in TSS concentrations in the 50 year ARI event in the upper Mahurangi is 19% and in the Pūhoi the increase is 9%. The estuary modelling has indicated that the change in TSS is temporary and after three days the TSS concentrations will have dropped back to near background levels.

Similarly the Pūhoi Estuary model indicates that the TSS concentrations are quickly deposited in the harbour or escape to open ocean, even in the scenarios with wind. After three days TSS concentrations were no greater than 50 g/m³.

Overall, we consider the effects on colour and clarity to be minor and the effects will be temporary.

9.3.6 Objectionable odour

Algal blooms and eutrophic conditions can cause objectionable odours. We do not expect the predicted increases in particular nutrients to cause the conditions that would result in noticeable a change in odour in the streams or marine environment. Therefore, with the proposed mitigation measures in place we consider the effects of the project on odour to be minor.

Overall, we consider the effects on aesthetics and odour to be minor and the effects will be temporary.

9.4 Human health

9.4.1 Criteria / consideration for the assessment

- i. introduce or increase the concentration of any determinands in the drinking water, so that, after existing treatment, it no longer meets the health quality criteria; or
- ii. introduce or increase the concentration of any aesthetic determinands in the drinking water so that, after existing treatment, it contains aesthetic determinands at values exceeding the guideline values

9.4.2 Human health

We have assessed the effect of the change in water quality associated 'with Project' on the potable water supply for Warkworth which is currently taken from the Mahurangi River, downstream of the Project.

The Project is expected to increase the level of sediment within the Mahurangi River, during the construction period, which can impact on the treatment of raw water. An increase in sediment will result in increased turbidity which has aesthetic effects. The release of sediment will also result in the release of particulate nitrogen. Nitrate and Nitrite are determinands with human health significance.

Watercare currently take raw water for Warkworth's potable water supply from a surface water take just upstream of Warkworth town centre. The raw water taken from the Mahurangi River is treated to meet drinking water standards.

Watercare are currently developing a bore water supply that they propose to be commissioned by 2016 and at that time is likely to be the main Warkworth water supply (P. Pererea, 2013, Pers. Comm., 9 July)

If the bore is the main source of drinking water during construction, with the surface water as a back-up supply, we consider the effects of the project on the human drinking water source to be minor.

However, we have also assessed the effects on surface water supply, to address the situation where the surface water remains the main source human drinking water for Warkworth, during construction.

The proposed increase in nutrients, during the construction period, is not expected to alter the quality of the source compared to NZ drinking water standard values (NZDWS 2008) for nitrite and nitrate, neither of which are elevated at the source in the existing situation.

The increase in TSS concentrations, due to the construction of the Project, is likely to increase turbidity levels within the Mahurangi River, by on average of 13%. The turbidity of surface water, within the Mahurangi River at the water take abstraction site, regularly exceeds the NZDWS 2008 values, but the water is treated by Watercare to meet the relevant NZDWS 2008 standards. However, Watercare prior to a recent upgrade, frequently had to close the Warkworth water treatment plant, due to elevated turbidity (P.Pererea, 2013, Pers Comm, 9 July)

In events up to an including the 2 year ARI event we assess no notable change in the probability distribution of sediment loads at the mouth of the Mahurangi River. Over 95% of all rainfall events are much smaller than the 2 year rain event.

In larger rainfall events we do anticipate that sediment loads that are experienced in the existing situation will occur slightly more frequently during construction. For example, in the 13 year event (7.4% chance of occurring one or more time in any given year in the existing situation), has a sediment load of 8249t. A sediment load of 8249t would be expected to occur more frequently and be a 10 year event during the construction period (10% chance of occurring once or more times in any given year).

Sediment ponds are expected to attenuate the construction sediment load. We expect a lag of between 24-48 hours when sediment ponds continue to discharge stormwater once streams have returned to baseflow. The effect of this attenuation on water quality in the lower Mahurangi River is likely to be small, due to the timing of inflows from other parts of the catchment.

We expect that the background sediment load would be the main driver for determining whether the Warkworth water treatment plant is required to close due to elevated turbidity. However, the increase in sediment load due to the Project may result in a small increase in the duration and or frequency of the closure of the Warkworth water treatment plant. Plant closures have been a relatively frequent occurrence. When the plant is closed drinking water is supplied from storage or by trucking in additional water (P.Pererea, 2013, Pers Comm, 9 July).

In the context of the construction water management techniques to be utilised within the Project; including, the open area limitations, the adaptive monitoring programme and the innovative

practices proposed, we consider the effects of the Project on surface water drinking source in the Mahurangi River to be minor to moderate.

9.5 Water users

9.5.1 Criteria / consideration for the assessment

- i. The rendering of freshwater unsuitable for consumption by farm animals (RMA Section 107)
- ii. Minimise effects on other water users
- iii. Water quality is safe for commercial and recreational activities (MAP)

9.5.2 Consumption by farm animals

We have assessed the predicted increase in sediment, and consider that the Project will have minor effect on the drinking water quality for stock.

9.5.3 Existing and foreseeable users

With the exception of the Watercare surface water abstraction on the Mahurangi River, there are no consented surface water abstractions on watercourses within the Pūhoi or Mahurangi catchments that are affected by the Project.

The permitted surface water abstraction rule in the Auckland Land Air and Water Plan, allows the taking and use of no more than 5m³/day of water from a river, stream or spring, subject to conditions. No information on permitted users is available from Auckland Council. We are aware of the Genesis Aquaculture Fish Farm on the M19 tributary of the Mahurangi. No water abstraction consent exists for this site, however for the purposes of this assessment we have assumed surface water is taken as a permitted activity for the fish farm. The monitoring site AC- FHQ is the closest water quality site to this farm.

The analysis we have undertaken has indicated that during rainfall events the TSS concentration in the stream is likely to exceed the water quality guidelines for freshwater aquaculture, however we would expect the background levels of TSS concentrations to also exceed this standard in many rainfall events. The likelihood of the water exceeding the guideline value is increased with the project. For example, at AC_FHQ site the 2 year ARI event sediment load has a 39% chance of occurring at least once in any given year which would be equivalent to 6 year ARI event sediment load in the background scenario, with a 15% chance of occurring at least once in any given year.

There may be a moderate effect on the fish farm as a specific water user, with increased sediment loads assuming no filtration of their water take. However the effect will be temporary, with TSS concentrations expected to return to background levels relatively quickly following events. This effect also needs to be placed within the context of the construction water management techniques to be utilised within the Project including the open area limitations, the adaptive monitoring programme and the innovative practices proposed.

From a marine perspective there are 42 marine farms consented in the Mahurangi Harbour. The effects assessment for these farms is addressed in the Marine Ecology Assessment Report.

Overall we consider the potential effect on existing and foreseeable water users to be minor with potential moderate effects depending on the proximity of users to the Project discharges.

9.5.4 Recreation

We have assessed the effects of the project on recreational values. In the freshwater receiving environments, the greatest changes in colour and clarity can be expected in the upper reaches of the rivers, however in the Hikauae and upper reaches of the Mahurangi River there is limited public access.

There is a popular swimming hole near Falls Road on the Mahurangi River. We expect the predicted changes in water clarity and colour to occur during and after rainfall events. The changes will coincide with changes and colour in clarity that would occur in the existing scenario, but may continue for a period of approximately 24-48 hours after the rainfall events. Changes in colour and clarity would be temporary.

In the marine environment, the mid to upper parts of the Mahurangi Estuary have poor clarity, generally less than 1.6 m and do not meet the ANZECC contact recreation water quality standards for clarity (ANZECC 2000).

It is recognised that both the Mahurangi and Pūhoi upper estuaries are popular for secondary contact (boating), but less popular for swimming. The clarity of the lower Mahurangi Estuary is good and colour is a fairly, bright 'blue-green' the water meets standards for contact recreation, with clarity generally greater than 1.6 m. (Davies-Colley, et al 2009).

We consider the temporary changes in colour and clarity associated with the Project will have minor effects on recreational values in the Pūhoi and Mahurangi, freshwater and marine environments.

9.6 Overall assessment

From an overall Project perspective we assess that the effects of the construction aspects of the Project are minor. A potential moderate effect exists associated with water uses however this will be temporary only.

Our overall assessment is outlined in the table below.

Table 39: Assessment criteria/ consideration

Matter for consideration	Project detail
Erosion and Sediment Control and Environmental Management including streamworks, and best practicable option (BPO) approach	<p>Environmental control measures will be fully implemented as part of the Project implementation. These will be implemented in accordance with CESCPS which will require future certification on an as-required basis.</p> <p>All discharges will be treated to a minimum standard associated with TP90. This standard is exceeded in many circumstances and includes chemical treatment, non-structural control measures, comprehensive methodologies and stabilisation techniques.</p> <p>Adaptive monitoring will take place which will measure the ongoing effectiveness of the ESC devices on the site, allow for effects assessment against receiving environment triggers and in turn allow for ongoing assessment and improvements of ESCs as necessary.</p>
Vegetation alteration, including removal/planting	<p>Vegetation removal will be required centred on the removal of exotic forestry areas within the Project indicative alignment.</p> <p>All vegetation removal is considered to meet the permitted activity conditions detailed within the ARP:SC.</p> <p>In addition to this the sequence of works is such that the ESCs will be established early in the project prior to vegetation removal operations.</p> <p>These controls will be fully operational and will remain throughout the entire works programme within the catchment of interest.</p>
Flooding	<p>During the construction phase of the project flooding has been considered, in particular during the design phase.</p> <p>Works within flood plain areas have been avoided as a first step such as those works immediately south of the SH1 intersection.</p> <p>Where works are required within flood plain areas such as those associated with culvert placement the risk profile is increased and the methodologies adapted for these areas.</p> <p>This includes ensuring that such works are undertaken during predicted fine weather windows and when weather conditions deteriorate ensuring that stabilised flow paths are available.</p>
Aesthetics and odour	<p>After reasonable mixing, sediment discharged is expected to give rise to minor increases in Conspicuous oil or grease films, scums or foams, floatable or suspended materials; and emission of objectionable odour.</p> <p>Changes are expected to be temporary.</p> <p>After reasonable mixing, sediment discharged is expected to give rise to a conspicuous change in colour and clarity, however changes are expected to be temporary.</p> <p>Environmental controls are comprehensive and reflect the best practical option approach while also adopting standards and monitoring of discharges.</p>

Matter for consideration	Project detail
Human impacts	<p>With the proposed mitigation in place and with the bore in place as a back-up supply, we consider the effects of the project on the potable water supply at Warkworth to be minor.</p> <p>With the proposed mitigation in place, and if Mahurangi River surface remains the main human drinking water source, we consider the effects of the project on the surface water drinking source to be minor to moderate. Construction water management techniques are considered to be innovative and represent industry best practice and any effects will be temporary only.</p>
Water users	<p>After reasonable mixing, we expect a minor effect on the water quality for stock drinking purposes.</p> <p>There may be minor to moderate but temporary, effects on water users abstracting water under the permitted rules.</p>

10. Recommendations and conclusions

The following key points are noted for the construction water management methodologies for the Project.

- The statutory framework and policy guidance from Auckland Council and the NZTA require that the Consent Holder be aware of and ensure implementation of appropriate construction water management controls including construction and maintenance of these devices.
- GLEAMS and USLE model calculations show a relatively low percentage increase in sediment yields for the Project from the background loads. However it is clear that those works associated with the steep topography of the Project are of higher risk than the Flat areas and need careful and pro-active management and monitoring to ensure that the construction effects are minor.
- A range of ESC measures are proposed on the Project. Where possible, these will be implemented in the same location as the long term stormwater structures and will at all times achieve as a minimum the requirements of TP90. ESCs will be based on both structural and non-structural measures with an emphasis placed on the non-structural management techniques. A range of innovative measures will be implemented.
- The Project's construction related water management will rely on CESCPS to be submitted to Auckland Council at a later date, before any construction activity takes place, to allow for contractor input.
- An adaptive monitoring programme will be implemented which will allow for ongoing water quality and ecological assessment of the construction programme. Continuous improvement of the construction water methodologies will form an integral part of this monitoring programme.

We recommend conditions of consent to ensure the effects of the Project are managed appropriately and remain minor. These conditions further ensure that the methodologies can be appropriately 'transferred' to the remaining parts of the Project.

The key condition framework we propose is summarised below.

Table 40: Summary of key condition framework

Condition framework	Condition comment and objective
ESC objectives	
<p>In managing earthworks and the potential for erosion and sediment runoff during construction of the Project, the Consent Holder should achieve a set of key objectives.</p> <p>i) To minimise the volume and area of the proposed earthworks required for the Project through the design of batter slopes and road alignments appropriate to expected soil types and geology;</p> <p>ii) To maximise the effectiveness of erosion and sediment control measures associated with earthworks by minimising</p>	<p>This condition is designed to ensure that the overall principles of the Report are reflected throughout the Project. This has the effect of ensuring a consistent approach throughout the project life and that construction activity reflects the approach within this Report.</p>

Condition framework	Condition comment and objective
potential for sediment generation and sediment yield; iii) To ensure that earthworks do not adversely affect receiving environments.	
Management Plans	
Preparation of an Erosion and Sediment Control Plan (ESCP) and Construction Erosion and Sediment Control Plans (CESCPs) for the Project.	<p>This condition allows for the preparation of a Project wide ESCP which will further define the specific management of construction water for the entire alignment.</p> <p>CESCPs will allow for site specific plans to be developed with contractor input, flexibility, innovation and specifics. The CESCPs will also ensure potentially affected parties are fully informed through the Project.</p>
Erosion and Sediment Control	
Design criteria specified for control measures.	This condition ensures that the design as specified in the Report is reflected throughout the project and can only be amended in the circumstance that a CESCP specifies a different design detail.
As built certification for erosion and sediment control measures.	This will ensure that controls are actually built and implemented as per the design. They will allow confirmation of achieving the design criteria to the regulatory agency.
Streamworks	
Prior to any streamworks commencing on the site, development of a final methodology for the streamworks, with particular emphasis on timing, staging and sequencing of streamworks. This should form part of a CESCP development process.	This will ensure that streamworks, which are identified as a high risk activity, are managed appropriately and take account of the necessary staging and sequencing provisions. This will include detailing the fish passage provisions and any seasonal restrictions that may apply.
Stabilisation	
<p>Open area limitations should apply to</p> <p>(a) Pūhoi Catchment – 41ha at any one time and;</p> <p>(b) Mahurangi Catchment – 41ha of Hill Country and 21.5ha of Flat (or equivalent ratios) at any one time.</p> <p>Review of open areas limitations should be subject to the results and analysis of the adaptive monitoring programme</p> <p>Progressive stabilisation within 10 working days of completion of earthworks within an area.</p>	<p>This condition will ensure that the sediment yields and effects remain within the effects envelope as determined from the Project.</p> <p>If a variation to this open area is proposed then this will be supported through the results of the adaptive monitoring programme and justified within the context of these outcomes over time.</p> <p>The 10 day progressive stabilisation provides confidence that progressive stabilisation will be put into practice and that areas of</p>

Condition framework	Condition comment and objective
	bare earth will not be left exposed for long periods of time when works are not occurring.
Winter Works Limitations	This will require winter works to be undertaken within a risk framework and will ensure that higher risk activities, such as working within the weathered clay soils, will be undertaken with care and within the risk profile as detailed within the Report.
Monitoring	
<p>An adaptive monitoring programme should be established which should follow the principles within the Report.</p> <p>An adaptive monitoring programme should include rainfall monitoring, automatic sampling and receiving environment surveys.</p> <p>The monitoring should provide analysis of sediment yields and the effects of any construction related discharges.</p> <p>The analysis of the results should allow the open area limitations to be reviewed.</p>	<p>This is designed to allow for informative decisions based on monitoring outcomes.</p> <p>It will further support the erosion and sediment controls that are being employed on the Project, and if these are shown to be ineffective then the monitoring programme allows for timely decisions to be made to adjust and review construction water design and methodology.</p> <p>The adaptive monitoring programme will also inform the extent of the open earthwork area limitations.</p>
Incident reporting	
Incident reporting and following relevant incident procedures and requirements. Where a failure of a control measure results in a discharge to a watercourse then reporting and remedial actions as necessary.	This will ensure an informative process continues and where an unexpected failure of control measure occurs the appropriate actions are put in place.
Training	
Ongoing training should form part of the Project prior to the commencement of work in any stage.	This condition will ensure that all Project staff are kept fully informed and trained as necessary with the details of the necessary environmental aspects of the Project and the various CESCps that will exist.

With the above condition framework and with the measures and methodologies in place as outlined in this Report, overall we assess the overall effects of the Project on the receiving environment to be minor.

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Appendix A. NZTA and TP90 ESC Principles

Auckland Regional Council

The "Ten Commandments" of Erosion and Sediment Control: 3 | 1

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Guidelines for Land Disturbing Activities in the Auckland Region

These "Ten Commandments" summarise the ten principles to follow when preparing an Erosion and Sediment Control Plan.

1. Minimise Disturbance

Fit land development to land sensitivity.

Some parts of a site should never be worked and others need very careful working. Watch out for and avoid areas that are wet (streams, wetlands, springs), have steep or fragile soils or are conservation sites or features.

Bear in mind the *minimum earthworks strategy (low impact design)* – ideally, only clear areas required for structures or access.

Show all Limits of Disturbance on the Erosion and Sediment Control Plan (E&SCP). On site, clearly show Limits of Disturbance using fences, signs and flags.

2. Stage Construction

Carrying out bulk earthworks over the whole site maximises the time and area that soil is exposed and prone to erosion. "Construction staging", where the site has earthworks undertaken in small units over time with progressive revegetation, limits erosion.

Careful planning is needed. Temporary stockpiles, access and utility service installation all need to be planned. Construction staging differs from sequencing. Sequencing sets out the order of construction to contractors.

Detail both construction staging and sequencing in the E&SCP.

3. Protect Steep Slopes

Existing steep slopes should be avoided. If clearing is absolutely necessary, runoff from above the site can be diverted away from the exposed slope to minimise erosion. If steep slopes are worked and need stabilisation, traditional vegetative covers like topsoiling and seeding may not be enough – special protection is often needed.

Highlight steep areas on the E&SCP showing Limits of Disturbance and any works and areas for special protection.

4. Protect Watercourses

Existing streams, watercourses and proposed drainage patterns need to be mapped. Clearing is not permitted adjacent to a watercourse unless the works have been approved by the Auckland Regional Council. Where undertaken, work that crosses or disturbs the watercourse

Map all watercourses and show Limits of Disturbance and protection measures; show all practices to be used to protect new drainage channels; and indicate crossings or disturbances and associated construction methods in the E&SCP.

5. Stabilise Exposed Areas Rapidly

The ultimate objective is to fully stabilise disturbed soils with vegetation after each stage and at specific milestones within stages. Methods are site specific and can range from conventional sowing through to straw mulching. Mulching is the most effective instant protection.

Clearly define time limits for grass or mulch covers, outline grass rates and species and define conditions for temporary cover in the case of severe erosion or poor germination in the E&SCP.

6. Install Perimeter Controls

Perimeter controls above the site keep clean runoff out of the worked area – a critical factor for effective erosion control. Perimeter controls can also retain or direct sediment laden runoff within the site. Common perimeter controls are diversion drains, silt fences and earth bunds.

Detail the type and extent of perimeter controls in the E&SCP along with design parameters.

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Guidelines for Land Disturbing Activities in the Auckland Region

7. Employ Detention Devices

Even with the best erosion and sediment practices, earthworks will discharge sediment laden runoff during storms. Along with erosion control measures, sediment retention structures are needed to capture runoff so sediment generated can settle out. The fine grained nature of Auckland soils means sediment retention ponds are often not highly effective. Ensure the other control measures used are appropriate for the project and adequately protect the receiving environment.

Include sediment retention structure design specifications; detailed inspection and maintenance schedules of structures and conversion plans for permanent structures, in the E&SCP.

8. Get Registered

A trained and experienced contractor is an important element of an E&SCP. These people are responsible for installing and maintaining erosion and sediment control practices. On-site staff certified through the Auckland Regional Council Industry Education Programme can save project time and money by identifying threatened areas early on and putting into place correct practices.

Contact Auckland Regional Council about registration. Include arrangements for a pre-construction meeting, regular inspection visits (including a pre-wintering meeting), and final inspection.

9. Make Sure the Plan Evolves

An effective E&SCP is modified as the project progresses from bulk earthworks to developed individual lots. Factors such as weather, changes to grade and altered drainage can all mean changes to planned erosion and sediment control practices.

Update the E&SCP to suit site adjustments in time for the pre-construction meeting and initial inspection of installed erosion and sediment controls, and make sure it is regularly referred to and available on site.

10. Assess and Adjust

Inspect, Monitor and Maintain Control Measures

Assessment of controls is especially important following a storm. A large or intense storm will leave erosion and sediment controls in need of repair, reinforcement or cleaning out. Repairing without delay reduces further soil loss and environmental damage.

Assessment and adjustment is an important erosion and sediment control practice – make sure it figures prominently in the E&SCP.

Assign responsibility for implementing the E&SCP and monitoring control measures as the project progresses.

4. Erosion and sediment control concepts

4.1 Key principle of erosion and sediment control

The overarching principle of erosion and sediment control on earthworks sites is to limit sediment transport and deposition. As a number of factors (e.g. rainfall intensity, soil composition) are beyond our control, it therefore falls to applying the most appropriate solution for the circumstances. As there are numerous devices at our disposal, the integration of as many concepts as possible provides the most effective erosion and sediment control on site (Georgetown County, 2006).

These concepts are typically formalised through the use of erosion and sediment control practices detailed in an Erosion and Sediment Control Plan (ESCP) prepared for the land disturbing activity.

4.2 Advantages of erosion and sediment control

With careful pre-planning, erosion and sediment controls usually result in many on-site advantages in addition to protecting the environment.

Environmental benefits include:

- Reduced risk of damage to aquatic ecosystems,
- Improved appearance of the site and downstream waters,
- Reduced water treatment costs,
- Reduced blockage of drains, and
- Less mud dropped or washed onto roads.

On-site benefits can typically include:

- Improved drainage and reduced site wetness as a result,
- Less dust problems,
- Improved working conditions,
- Reduced downtime after rain,
- Less stockpile losses,
- Reduced clean-up costs,
- Earlier works completion, and
- Less chance of public complaints.

4.3 Concepts and principles of erosion and sediment control

Implementation of erosion and sediment controls is required to avoid, remedy or mitigate the effects of earthworks on the receiving environment. To ensure that erosion and sediment controls are effective and cost efficient, an understanding of the basic principles of erosion and sediment control is required, as is ensuring that erosion and sediment control practices are considered and carefully managed throughout the project's planning, design and construction phases (Environment Canterbury, 2007).

State highway project's construction timeframes may take longer to construct than other types of construction projects, and the resulting longer operational life of many erosion and sediment controls, requires a stronger emphasis on some management concepts (Department of Environment and Climate Change NSW, June 2008), particularly:

- The control of upper catchment water,
- Separation of clean from dirty water,
- Protecting the land surface from erosion, and
- Preventing sediment from leaving the site.

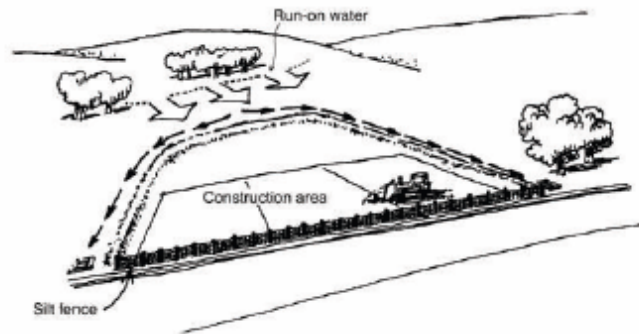
The following concepts are therefore relevant when designing an erosion and sediment control plan for a state highway project site.

4.3.1 Control upper catchment water

Upper catchment water is runoff from above the area of disturbance that would normally flow through the site. The key consideration in reducing the contributing catchment is to control this clean water by interception, diversion and safe disposal to a location below the area of disturbance as shown in Figure 4.1.

Reducing the area of the catchment contributing to water flowing through the site will reduce the volume of water to be treated thereby minimising the sizing of any controls.

Figure 4.1
Diversion of clean water from above the site (Goldman et al 1986)



Diversion separating the clean water from the dirty water

4.3.2 Separate clean from dirty

Clean water is water that has not flowed through disturbed areas whilst discharges from disturbed areas are considered to be dirty water. Minimising the volume of water that is required to be treated by a sediment control device saves space and money. Furthermore clean water (upper catchment water that does not flow through the disturbed area) has not been contaminated by sediment, therefore does not require treatment. Practices to achieve this are outlined in Section 7 of this standard.



4.3.3 Reduce the area available for erosion

To minimise the rates of soil loss, techniques as outlined in section 8 of this standard will assist however, protecting the land surface from erosion can be as simple as:

- Project design taking into account terrain limitations,
- Project scheduling to known climatic and soil variations,
- Minimising land clearance,
- Limiting areas of disturbance, and
- Progressively stabilising disturbed areas (e.g. grassing and mulching)

Erosion Control – Mulching



4.3.4 Minimise sediment from leaving the site

Sediment laden water (dirty water), as discussed in previous sections, can have a variety of impacts if not managed in accordance with best practice. Therefore it is imperative that a suite of controls are used on state highway construction projects. Sediment controls should be selected taking into account the site constraints and receiving environment, and steps should be taken to ensure that the controls are integrated with the permanent features of the project. Refer to the practices outlined in section 8.

Sediment Control Practices



4.4 The role of erosion and sediment controls

Erosion and sediment controls have different roles on an earthworks site. Erosion controls seek to minimise any sediment from being mobilised whilst sediment controls attempt to remove sediment from suspension once entrained. The analogy of erosion controls (fence at the top of the cliff) whilst sediment controls (ambulance at the bottom of the cliff) is applicable in describing their roles.

Any ESCP should place initial emphasis on erosion control although in many circumstances this may not be achievable.

4.4.1 Efficiency vs effectiveness of practices

The ability of an erosion and sediment control practice to prevent sediment from being transported or to remove sediment once entrained is a measure of its efficiency. This efficiency (as a %) can be represented as the volume removed when measured against the volume of sediment that arrives at the practice. Depending on a range of factors the removal efficiency can range from 50% to 75%.

Efficiency should not be confused with effectiveness. The effectiveness of a specific practice takes into consideration other factors such as the timing, cost, sensitivity of receiving environment and placement location of the device. For example, a sediment retention pond placed in an area that receives little or no water is still an efficient practice but is not an effective measure for that particular site.

4.5 The treatment train

A treatment train comprises a series of best management practices and/or natural features, each planned to treat a different aspect of pollution prevention, that are implemented in a linear fashion to maximise pollutant removal. This approach is directly applicable to the control of sediment on state highway projects.

Erosion and sediment control measures should generally be planned to link functionally to form a "treatment train" with each measure having a



specific role within the framework of surface water management, soil protection and stabilisation, and sediment capture. This approach can be a combination of structural (e.g. sediment ponds, hydroseeding) and non-structural (e.g. earthworking season) practices.

This approach needs to be considered during the early phases of project planning, and followed through to the completion of the project. Section 5 of this document will detail how to select the appropriate tools to ensure that this approach occurs.

4.6 Principles to follow

These ten principles (best practice principles) build upon the previous concepts and provide guidance for erosion and sediment control through the planning, construction and maintenance phase of a project

4.6.1 Minimise disturbance

Fit earthworks, construction techniques and methodologies to land sensitivity. This may be difficult from a state highway perspective where space is limited but the concept should always be considered.

Some parts of a site should never be worked and others need very careful working. Watch out for and, if practicable, avoid areas that are wet (streams, wetlands and springs), have steep or fragile soils or are conservation sites or features.

Bear in mind a minimum earthworks strategy and only clear areas required for structures or access.

Show all limits of disturbance on the ESCP. On site, clearly show the limits of disturbance using fences, signs and flags.

Highway Construction Site – Minimising Disturbance



4.6.2 Stage construction

Carrying out bulk earthworks over the whole site maximises the time and area that soil is exposed and prone to erosion. "Construction staging", where the site has earthworks undertaken in small units over time with progressive revegetation, limits erosion.

Careful planning is needed. Temporary stockpiles, access and utility service installation all need to be planned. Construction staging differs from sequencing. Sequencing sets out the order of construction to contractors. Detail both construction staging and sequencing in the ESCP.

Flume Installed to Protect Steep Slope



4.6.3 Protect Steep Slopes

Where possible avoid existing steep slopes. If clearing of steep slopes is necessary, runoff from above the site can be diverted away from the exposed slope to minimise erosion. If steep slopes are worked and need stabilisation, traditional vegetative covers like

topsoiling and seeding may not be enough - special protection is often needed.
Highlight steep areas on the ESCP showing limits of disturbance and any works and areas for special protection.

4.6.4 Protect watercourses

Existing streams and watercourses, and proposed drainage patterns need to be mapped. Resource consent may be required for clearance works adjacent to a watercourse.

Map all watercourses and show all limits of disturbance and protection measures in the ESCP. Also, the ESCP should show all practices to be used to protect new drainage channels. Indicate crossing or disturbances and associated construction methods in the ESCP.

Sediment Discharge as a Result of Not Protecting the Watercourse



4.6.5 Stabilise exposed areas rapidly

An important objective is to fully stabilise disturbed soils with vegetation after each stage and at specific milestones within stages. Methods are site specific and can range from conventional sowing through to straw mulching. Mulching is the most effective instant protection.

In the ESCP clearly define time limits for grass or mulch application, outline grass rates and species and define conditions for temporary cover in the case of severe erosion or poor germination.

Rapid Stabilisation



4.6.6 Install perimeter controls

Perimeter controls above the site keep clean runoff out of the worked area - a critical factor for effective erosion control. Perimeter controls can also retain or direct sediment laden runoff within the site. Common perimeter controls are diversion drains, silt fences and earth bunds.

Detail the type and extent of perimeter controls in the ESCP along with the design parameters for those controls.

Types of Perimeter Controls



4.6.7 Employ detention devices

Even with the best erosion and sediment practices, earthworks will discharge sediment laden runoff during storms. Along with erosion control measures, sediment retention structures are needed to capture runoff so sediment generated can settle out. Sediment retention ponds are often not highly effective in areas with fine grained soils. In those areas it is necessary to ensure the other control measures used are appropriate for the project and adequately protect the receiving environment.

Include sediment retention structure design specifications; detailed inspection and maintenance schedules of structures and conversion plans for permanent structures, in the ESCP.

Sediment Retention Pond



4.6.8 Experience and training

A trained and experienced contractor is an important element of an ESCP. Contractors are individuals responsible for installing, maintaining and decommissioning erosion and sediment control practices.

Critical on-site staff should go through an erosion and sediment control training programme that may be available either locally or elsewhere in New Zealand. The NZTA also has an e-learning module on erosion and sediment control in development. Better knowledge can save project time and money, by allowing for identification of threatened areas early on and putting into place correct practices.



Making arrangements for a pre-construction meeting, regular inspection visits, and final inspection is also important.

4.6.9 Make sure the plan evolves

An effective ESCP is modified as the project progresses from bulk earthworks to permanent drainage and stabilisation. Factors such as weather, changes to grade and altered drainage can all mean changes to planned erosion and sediment control practices.

Update the ESCP to suit site adjustments in time for the pre-construction meeting and initial inspection of installed erosion and sediment controls, and make sure it is regularly referred to and available on site.

4.6.10 Assess and adjust

Inspect, monitor and maintain control measures.

Assessment of controls is especially important following a storm. A large or intense storm will leave erosion and sediment controls in need of repair, reinforcement or cleaning out. Repairing without delay reduces further soil loss and environmental damage.

Assessment and adjustment is an important erosion and sediment control practice - make sure it figures prominently in the ESCP.

Assign responsibility for implementing the ESCP and monitoring control measures as the project progresses.

The ESCP should also be integrated with the Contractor's Social and Environmental Management Plan, therefore, reducing duplication in the site specific environmental aspect management plans.

Undertaking Maintenance of a Sediment Retention Pond



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Appendix B. NZTA ESC Checklists

Appendix A – Preconstruction meeting checklist

 NZ TRANSPORT AGENCY <small>WAKA KOTAHU</small>	<h2 style="text-align: center;">Preconstruction Meeting Checklist</h2>		Contractor	
			Date:	
			Consent #:	
			Site:	
Attendees	Affiliation	Phone Number	Email address	
Items Discussed			Check if Discussed	
Resource consent conditions	Who has copies			
	Is the consent on site			
	All conditions clear and understood			
	Are any conditions specific to this site only			
	Erosion and sediment control plan approved			
	Winter works			
	Any outstanding issues			
Communication	Key individuals and contact details exchanged			
	Regulatory authority inspection procedures			
	Line of responsibility for each party			
Erosion and sediment control plan	Go over plan			
	Highlight critical areas where extra care must be taken			
	Discuss any needed field modifications to the plan			
	Discuss project phasing if that is a project element			
Maintenance of erosion and sediment controls	Discuss the need for 'As Built' certification per local requirements			
	Discuss the periodic need for maintenance and material replacement. Are there any issues related to replacement?			
	Discuss when maintenance needs to be accomplished			
Site stabilisation	Discuss project time frames and any staging of activities			
	Discuss project phasing and when stabilisation must be done			
Decommissioning	Discuss what degree of stabilisation is required for sediment control practices to be removed.			
Preconstruction meeting minutes	Ensure that all parties are provided with any notes made at the meeting.			

Appendix C. Mass Haul Spreadsheet Calculations

Item	Zone	Qty	Unit	Year-1 May-Oct	Year-2 Nov-Apr	Year-2 May-Oct	Year-3 Nov-Apr	Year-3 May-Oct	Year-4 Nov-Apr	Year-4 May-Oct	Year-5 Nov-Apr	Year-5 May-Oct
Cut to Fill (1)	Zone-1	-	m3	-	-	-	-	-	-	-	-	-
Import Fill (Construction Zone)	Zone-1	47,616	m3	-	-	-	-	-	-	-	47,616	-
Cut to Fill (2)	Zone-1	-	m3	-	-	-	-	-	-	-	-	-
Cut to Waste	Zone-1	-	m3	-	-	-	-	-	-	-	-	-
Undercut and Unsuitable	Zone-1	1,538	m3	-	-	-	-	-	-	-	1,538	-
Total Earthworks	Zone-1	1,538	m3	-	-	-	-	-	-	-	1,538	-
Earthworks Area	Zone-1	14,415	m2	-	-	-	-	-	-	-	14,415	-
Spoil Area	Zone-1	205	m2	-	-	-	-	-	-	-	205	-
Total Area	Zone-1	14,620	m2	-	-	-	-	-	-	-	14,620	-
Cut to Fill (1)		335,393	m3	-	207,781	-	-	-	127,612	-	-	-
Import Fill (Construction Zone)	Zone-3	322,361	m3	-	-	-	-	-	-	-	322,361	-
Cut to Fill (2)	Zone-3		m3	-	-	-	-	-	-	-	-	-
Cut to Waste	Zone-3	-	m3	-	-	-	-	-	-	-	-	-
Undercut and Unsuitable	Zone-3	166,024	m3	-	107,013	-	24,488	-	34,523	-	-	-
Total Earthworks	Zone-3	501,417	m3	-	314,794	-	24,488	-	162,135	-	-	-
Earthworks Area	Zone-3	132,827	m2	-	104,842	-	6,780	-	78,316	-	42,429	-
Spoil Area	Zone-3	22,137	m2	-	14,268	-	3,265	-	4,603	-	-	-
Total Area	Zone-3	154,964	m2	-	119,111	-	10,045	-	82,919	-	42,429	-
Cut to Fill (1)	Zone-5	752,665	m3	-	166,910	-	337,804	-	247,951	-	-	-
Import Fill (Construction Zone)	Zone-5		m3	-	-	-	-	-	-	-	-	-
Cut to Fill (2)	Zone-5	432,530	m3	-	-	-	-	-	62,553	-	369,977	-
Cut to Waste	Zone-5	353,330	m3	-	-	-	-	-	203,986	-	149,344	-
Undercut and Unsuitable	Zone-5	428,198	m3	-	111,550	-	211,577	-	59,687	-	45,384	-
Total Earthworks	Zone-5	1,966,722	m3	-	278,460	-	549,381	-	574,177	-	564,704	-
Earthworks Area	Zone-5	316,192	m2	-	78,731	-	179,575	-	149,333	-	68,831	-
Spoil Area	Zone-5	104,204	m2	-	14,873	-	28,210	-	35,156	-	25,964	-
Total Area	Zone-5	420,396	m2	-	93,604	-	207,785	-	184,489	-	94,794	-
Cut to Fill (1)	Zone-6B	15,131	m3	-	-	-	-	-	15,131	-	-	-
Import Fill (Construction Zone)	Zone-6B	62,553	m3	-	-	-	-	-	62,553	-	-	-
Cut to Fill (2)	Zone-6B		m3	-	-	-	-	-	-	-	-	-
Cut to Waste	Zone-6B		m3	-	-	-	-	-	-	-	-	-
Undercut and Unsuitable	Zone-6B	58,765	m3	-	-	-	-	-	58,765	-	-	-
Total Earthworks	Zone-6B	73,896	m3	-	-	-	-	-	73,896	-	-	-
Earthworks Area	Zone-6B	16,238	m2	-	-	-	-	-	16,238	-	-	-
Spoil Area	Zone-6B	7,835	m2	-	-	-	-	-	7,835	-	-	-
Total Area	Zone-6B	24,073	m2	-	-	-	-	-	24,073	-	-	-
Cut to Fill (1)	Zone-7A	624,633	m3	-	-	-	231,892	-	392,741	-	-	-
Import Fill (Construction Zone)	Zone-7A		m3	-	-	-	-	-	-	-	-	-
Cut to Fill (2)	Zone-7A	52,856	m3	-	-	-	-	-	-	-	52,856	-
Cut to Waste	Zone-7A	161,250	m3	-	-	-	-	-	-	-	161,250	-
Undercut and Unsuitable	Zone-7A	230,914	m3	-	40,286	-	110,950	-	79,678	-	-	-
Total Earthworks	Zone-7A	1,069,653	m3	-	40,286	-	342,842	-	472,419	-	161,250	52,856
Earthworks Area	Zone-7A	200,068	m2	-	26,688	-	148,397	-	105,388	-	51,946	25,973
Spoil Area	Zone-7A	52,288	m2	-	5,371	-	14,793	-	10,624	-	21,500	-
Total Area	Zone-7A	252,357	m2	-	32,059	-	163,191	-	116,012	-	73,446	25,973
Cut to Fill (1)	Zone-7B	2,256,610	m3	-	231,020	-	442,213	442,213	380,388	380,388	380,388	-
Import Fill (Construction Zone)	Zone-7B		m3	-	-	-	-	-	-	-	-	-
Cut to Fill (2)	Zone-7B	661,944	m3	-	-	-	-	-	-	-	-	661,944
Cut to Waste	Zone-7B		m3	-	-	-	-	-	-	-	-	-
Undercut and Unsuitable	Zone-7B	523,816	m3	-	71,089	-	97,070	131,484	33,999	33,999	33,999	122,176
Total Earthworks	Zone-7B	3,442,370	m3	-	302,109	-	539,282	573,697	414,388	414,388	414,388	784,120
Earthworks Area	Zone-7B	408,040	m2	-	132,910	-	179,840	179,840	236,228	236,228	236,228	82,838
Spoil Area	Zone-7B	69,842	m2	-	9,479	-	12,943	17,531	4,533	4,533	4,533	16,290
Total Area	Zone-7B	477,882	m2	-	142,388	-	192,783	197,372	240,761	240,761	240,761	99,128

Cut to Fill (1)	Zone-9A	566,678	m3	-	-	-	282,574	-	284,104	-	-	-	-
Import Fill (Construction Zone)	Zone-9A	38,840	m3	-	-	-	-	-	-	-	-	38,840	-
Cut to Fill (2)	Zone-9A		m3										
Cut to Waste	Zone-9A		m3										
Undercut and Unsuitable	Zone-9A	98,453	m3	-	10,490	-	49,509	-	38,454	-	-	-	-
Total Earthworks	Zone-9A	665,131	m3	-	10,490	-	332,083	-	322,558	-	-	-	-
Earthworks Area	Zone-9A	124,313	m2	-	10,676	-	124,313	-	92,286	-	-	34,385	-
Spoil Area	Zone-9A	13,127	m2	-	1,399	-	6,601	-	5,127	-	-	-	-
Total Area	Zone-9A	137,440	m2	-	12,074	-	130,914	-	97,413	-	-	34,385	-
Cut to Fill (1)	Zone-9C	352,409	m3	-	-	-	-	-	-	-	352,409	-	-
Import Fill (Construction Zone)	Zone-9C	531,239	m3	-	-	-	-	-	-	-	-	531,239	-
Cut to Fill (2)	Zone-9C		m3										
Cut to Waste	Zone-9C		m3										
Undercut and Unsuitable	Zone-9C	162,796	m3	-	-	-	-	-	52,935	-	109,861	-	-
Total Earthworks	Zone-9C	515,205	m3	-	-	-	-	-	52,935	-	462,270	-	-
Earthworks Area	Zone-9C	221,775	m2	-	-	-	-	-	53,874	-	221,775	161,621	-
Spoil Area	Zone-9C	21,706	m2	-	-	-	-	-	7,058	-	14,648	-	-
Total Area	Zone-9C	243,481	m2	-	-	-	-	-	60,932	-	236,423	161,621	-
Cut to Fill (1)	Zone-11	162,341	m3	-	-	-	122,357	-	39,984	-	-	-	-
Import Fill (Construction Zone)	Zone-11	144,720	m3	-	-	-	-	-	-	-	-	144,720	-
Cut to Fill (2)	Zone-11		m3										
Cut to Waste	Zone-11		m3										
Undercut and Unsuitable	Zone-11	97,312	m3	-	21,874	-	62,110	-	13,328	-	-	-	-
Total Earthworks	Zone-11	259,653	m3	-	21,874	-	184,467	-	53,312	-	-	-	-
Earthworks Area	Zone-11	148,312	m2	-	13,796	-	85,995	-	83,351	-	-	75,194	-
Spoil Area	Zone-11	12,975	m2	-	2,916	-	8,281	-	1,777	-	-	-	-
Total Area	Zone-11	161,287	m2	-	16,713	-	94,277	-	85,128	-	-	75,194	-
Cut to Fill (1)	Puhoi Catchment	1,727,822	m3	-	374,691	-	569,696	-	783,435	-	-	-	-
Import Fill (Construction Zone)	Puhoi Catchment	432,530	m3	-	-	-	-	-	62,553	-	369,977	-	-
Cut to Fill (2)	Puhoi Catchment	485,386	m3	-	-	-	-	-	62,553	-	369,977	52,856	-
Cut to Waste	Puhoi Catchment	514,580	m3	-	-	-	-	-	203,986	-	310,593	-	-
Undercut and Unsuitable	Puhoi Catchment	885,439	m3	-	258,849	-	347,016	-	232,653	-	46,922	-	-
Total Earthworks	Puhoi Catchment	3,613,227	m3	-	633,540	-	916,712	-	1,282,627	-	727,492	52,856	-
Earthworks Area	Puhoi Catchment	679,741	m2	-	210,261	-	334,752	-	349,275	-	177,621	25,973	-
Spoil Area	Puhoi Catchment	186,669	m2	-	34,513	-	46,269	-	58,219	-	47,669	-	-
Total Area	Puhoi Catchment	866,410	m2	-	244,774	-	381,021	-	407,494	-	225,290	25,973	-
Cut to Fill (1)	Mahurangi Catchment	3,338,038	m3		231,020	-	847,144	442,213	704,476	380,388	732,797	-	-
Import Fill (Construction Zone)	Mahurangi Catchment	714,799	m3		-	-	-	-	-	-	-	714,799	-
Cut to Fill (2)	Mahurangi Catchment	661,944	m3		-	-	-	-	-	-	-	661,944	-
Cut to Waste	Mahurangi Catchment	-	m3		-	-	-	-	-	-	-	-	-
Undercut and Unsuitable	Mahurangi Catchment	882,377	m3		103,452	-	208,689	131,484	138,716	33,999	143,860	122,176	-
Total Earthworks	Mahurangi Catchment	4,882,359	m3		334,472	-	1,055,833	573,697	843,193	414,388	876,657	784,120	-
Earthworks Area	Mahurangi Catchment	902,439	m2		157,382	-	390,149	179,840	465,738	236,228	458,002	354,038	-
Spoil Area	Mahurangi Catchment	117,650	m2		13,794	-	27,825	17,531	18,495	4,533	19,181	16,290	-
Total Area	Mahurangi Catchment	1,020,089	m2		171,175	-	417,974	197,372	484,233	240,761	477,184	370,328	-
Cut to Fill (1)	Project Total	5,065,860	m3	-	605,711	-	1,416,840	442,213	1,487,911	380,388	732,797	-	-
Import Fill (Construction Zone)	Project Total	1,147,329	m3	-	-	-	-	-	62,553	-	369,977	714,799	-
Cut to Fill (2)	Project Total	1,147,330	m3	-	-	-	-	-	62,553	-	369,977	714,800	-
Cut to Waste	Project Total	514,580	m3	-	-	-	-	-	203,986	-	310,593	-	-
Undercut and Unsuitable	Project Total	1,767,816	m3	-	362,301	-	555,705	131,484	371,369	33,999	190,782	122,176	-
Total Earthworks	Project Total	8,495,585	m3	-	968,012	-	1,972,544	573,697	2,125,819	414,388	1,604,150	836,976	-
Earthworks Area	Project Total	1,582,180	m2	-	367,642	-	724,901	179,840	815,013	236,228	635,623	380,011	-
Spoil Area	Project Total	304,319	m2	-	48,307	-	74,094	17,531	76,714	4,533	66,850	16,290	-
Total Area	Project Total	1,886,500	m2	-	415,949	-	798,995	197,372	891,727	240,761	702,473	396,301	-