IN THE MATTER OF	The Resource Management Act 1991
AND	
IN THE MATTER OF	applications for resource consents in relation to Te Ahu a Turanga; Manawatū Tararua Highway Project
BY	**NEW ZEALAND TRANSPORT AGENCY** Applicant

TE AHU A TURANGA: TECHNICAL ASSESSMENT A

EROSION AND SEDIMENT CONTROL

TABLE OF CONTENTS

INTRODUCTION

1. My name is **Campbell Ross Stewart**.

2. I am a Director of Southern Skies Environmental Limited ("**SSEL**"), an environmental consultancy company specialising in erosion and sediment control ("**ESC**"), environmental management and planning.

3. This technical assessment will consider the erosion and sediment effects during the construction phase of the Te Ahu a Turanga; Manawatū Tararua Highway Project (the "**Project**"). Accompanying this assessment are:

   (a) an overarching ESC Plan, which is provided in **Volume VII** ("**ESCP**") and which includes (but is not limited to):

      (i) an ESC Monitoring Plan ("**ESCMP**"); and

      (ii) a Chemical Treatment Management Plan ("**CTMP**")

   (b) Concept ESC Drawings ("**Concept ESC Drawings**"), which are provided in the **Drawing Set, Volume III**; and

   (c) three example Site Specific ESC Plans ("**SSESCPs**"), which are also provided in the **Drawing Set, Volume III**..

Qualifications and experience

4. I have the following qualifications and experience relevant to this assessment:

   (a) I have a Bachelor of Resource Studies from Lincoln University, Lincoln (1994).

   (b) I am a Certified Professional in Erosion and Sediment Control (CPESC Number 7630), a qualification that is achieved through Envirocert International and the International Erosion Control Association.

   (c) Prior to forming SSEL, I was employed as an environmental and ESC consultant with Babingtons and Associates providing specialist ESC management services to Auckland Regional Council. Prior to that I was employed by the Waikato Regional Council as a Land Management Officer.

   (d) A particular focus of my career has been in the field of ESC in which I have over 25 years' experience. I have been involved in assessing and monitoring significant earthworks projects since 1998. I have a broad range of experience in ESC, including detailed involvement with councils and the construction industry.

(e) Since 2008 I have been involved in designing and working with construction teams to implement, monitor and maintain ESC and environmental devices and methodologies for a number of large infrastructure projects across New Zealand.

(f) I have extensive experience in earthworks, stream works and construction activities. This includes involvement with policy development and implementation, education and training and regulation covering all aspects of the ESC process.

(g) I have specific experience in both preparing technical assessments to support the Resource Management Act 1991 ("**RMA**") process as well as on-site experience with a number of Waka Kotahi NZ Transport Agency ("**Transport Agency**") roading projects including, but not limited to, Huntly Bypass, East Taupo Arterial, Tauranga Eastern Link, Auckland North Western Motorway upgrade projects including the Causeway Upgrade, the Waikato Expressway Te Rapa section and the Northern Motorway Albany to Puhoi Sections B1 and B2. Having been directly involved with all ESC aspects of these projects I am aware of the issues, opportunities and practicalities that can arise between the planning phase and on-site implementation.

(h) I was the lead technical author of the Auckland Council Guideline Document 05 'Erosion and Sediment Control Guide for Land Disturbing Activities in the Auckland Region' ("**GD05**") for the management of erosion and sediment associated with construction sites. GD05 is considered the current best practice guideline in New Zealand for ESC management. GD05 is a key guideline promoted and used by Auckland Council and a number of other councils across New Zealand.

(i) I am a past director of the Australasian Chapter of the International Erosion Control Association.

(j) I am a past member of the Certified Professional in Erosion and Sediment Control Ethics Committee Australasia and have recently been appointed to the Australasia CPESC Exam Making Panel.

(k) I have been an expert witness for two Environment Court prosecutions under the RMA and approximately 20 planning hearings.

Code of conduct

5. I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2014. This assessment has been

prepared in compliance with that Code, as if it were evidence being given in Environment Court proceedings. In particular, unless I state otherwise, this assessment is within my area of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

Purpose and scope of assessment

6. I have been engaged to advise on and design the ESC methodology to be implemented during the construction phase of the Project and provide a corresponding assessment of the likely erosion and sediment related effects associated with the Project's construction.

7. The scope of my assessment has involved:

   (a) a description and understanding of the receiving environment as it is relevant to my assessment;

   (b) an investigation and assessment of the potential sediment yields and sediment yield determining factors;

   (c) identification and recommendation of ESC methods, practices and standards to be implemented and complied with as far as practicable during construction in order to avoid, remedy or minimise potential effects during construction of the Project; and

   (d) development of the ESCP, ESCMP, CTMP, Concept ESC Drawings and example SSESCPs.

8. In the course of this work I have visited the Project Area on several occasions throughout 2019. I have walked large sections of the Alignment with members of the Project's construction team[1] and discussed and planned construction techniques and methodologies.

9. This ESC Assessment should be read in conjunction with:

   (a) **Mr Tim Watterson's** Design and Construction Report ("**DCR**"), which is provided in **Volume II**;

   (b) **Mr Kaching Cheng's** Geotechnical Design Technical Memorandum (**Appendix A of the DCR**), which provides the geological setting of the Alignment and the design approach that has been taken to address these geological and geotechnical characteristics;

[1] Tony Adams, Construction Manager, Hardus Pieters, Enabling and Civil Construction Manager, Clare Miller, Earthworks Manager.

(c) **Mr David Hughes'** Stormwater Management Assessment (**Technical Assessment B in Volume IV**);

(d) **Mr Keith Hamill's** Water Quality Assessment (**Technical Assessment C in Volume IV**), which covers the impacts of the stormwater discharges on water quality in the receiving environment;

(e) **Dr Jack McConchie's** Hydrological Assessment (**Technical Assessment D in Volume IV**), which covers the design rainfalls that have influenced the design of stormwater management devices, the impacts of the stormwater discharges on water quantity in the receiving environment, a hydraulic assessment of key Project elements (including the two Bridges and the Eastern Roundabout), and a flood hazard assessment;

(f) **Mr Richard Chilton's** Air Quality Assessment (**Technical Assessment E in Volume IV**) which includes an assessment of potential dust effects during construction.

(g) **Ms Justine Quinn's** Freshwater Ecological Assessment (**Technical Assessment H in Volume V**);

EXECUTIVE SUMMARY

10. The Project consists of approximately 11.5km of State Highway connecting Ashhurst and Woodville via a route over the southern end of the Ruahine Ranges. I have provided a design and assessment of the ESC measures and management approach to be implemented during the construction phase of the Project. My role has included the preparation of related management plans, namely the ESCP and its appendices.

11. The Project is within catchments of the Pohangina River and the Manawatū River and directly effects nine smaller catchments. Water quality across the catchments is varied. The baseline monitoring found that most sites had relatively low visual clarity, moderately high turbidity, with the exception of Catchment 7, which had a relatively high proportion of fine sediment on the stream bed.

12. The objectives of the ESC management of the Project are:

(a) To minimise the potential for sediment generation and sediment yield by maximising the effectiveness of ESC measures associated with earthworks; and

(b) To take all reasonable steps to avoid or minimise potential adverse effects on freshwater environments within or beyond the Project Area that may arise from the discharge of sediment during the construction of the Project.

13. After site walkovers, extensive liaison with the Project design team and specialists, and discussions with Horizons Regional Council (**"Horizons"**), I have prepared an ESC design approach based on GD05, which represents industry best practice and will minimise the discharge of sediment during the construction phase to an acceptable extent, and ensure that any potential adverse off-site effects are temporary.

14. The assessment of potential effects from the discharge of treated sediment laden runoff to the freshwater receiving environments has been based on estimates of sediment yield for various parts of the Project Area, using the Universal Soil Loss Equation ("**USLE**"). Having considered USLE estimates undertaken for other Transport Agency, infrastructure and land development projects that I am familiar with, and comparing those project ULSE estimates with recorded sediment retention pond ("**SRP**") performance within the other sites, I am satisfied that the sediment yield estimates undertaken for the Project are realistic and likely to be conservatively high, when compared to likely actual sediment yields that will occur during construction.

15. The sediment yield estimates have been further validated by an analysis of the responsiveness of various soils along the Alignment to chemical treatment, which will maximise treatment device efficiency by enhancing settlement rates.

16. The ESC management of the Project will be guided by the ESCP which describes the overall principles and methodology to be adopted. The ESCP is supported by a range of management plans and procedures; including Concept ESC Drawings, a CTMP and the ESCMP, which details the extensive and ongoing monitoring and maintenance of ESC measures that will be implemented throughout the construction period. This will include additional monitoring of the performance of SRPs and decanting earth bunds ("**DEBs**") during or immediately after specific rainfall trigger events.

17. The detail of the ESC measures to be implemented within a given area of the Project will be provided in SSESCPs. Those plans will provide the design detail of individual ESC measures to be implemented in an area and will be prepared and submitted to Horizons for certification against GD05 and relevant consent conditions, prior to works commencing in that area.

18. The maintenance of best practice ESC will be driven by a dedicated Environmental Management Team, led by the Environmental Manager, and

supported by an Environmental Technical Specialist, Environmental Coordinator, Environmental Supervisor. Day to day operation and maintenance of ESC measures will be undertaken by ESC Foremen and ESC Labourers.

19. The Project Environmental Management Team and Construction Management Team will work closely with Horizons compliance monitoring inspectors for the duration of the Project, to ensure a high standard of compliance and a no-surprises approach to design changes and site management.

PROJECT DESCRIPTION

20. The Project comprises the construction, operation and maintenance of approximately 11.5km of State Highway connecting Ashhurst and Woodville via a route over the Ruahine Ranges. The purpose of the Project is to replace the indefinitely closed existing State Highway 3 ("**SH3**") through the Manawatū Gorge.

21. The Project comprises a median separated carriageway that includes two lanes in each direction over the majority of the route and will connect with State Highway 57 ("**SH57**") east of Ashhurst and SH3 west of Woodville (via proposed roundabouts). A shared use path for cyclists and pedestrian users is proposed as well as a number of new bridge structures including a bridge crossing over the Manawatū River.

22. The design and detail of each of the elements of the Project are described in:

    (a) Section 3 of the Assessment of Environmental Effects (contained in **Volume I**);

    (b) the DCR (contained in **Volume II**); and

    (c) the Drawing Set (contained in **Volume III**).

23. The DCR contains a full description of the proposed construction method for the Project and this is not repeated in full below. However, key elements relevant to this ESC Assessment are set out below:

    (a) The Project will require approximately 195ha of earthworks. This has been calculated as a worst-case earthworks area.

    (b) The total earthworks area includes the main Alignment and the following:

        (i) access tracks;
        (ii) Te Āpiti Wind Farm tracks;
        (iii) spoil disposal sites; and

(iv) temporary stockpiling, laydown and yard areas.

(c) Of the 195ha of total earthworks, on an aerial basis approximately 30% is expected to occur within the Mangamanaia stream catchment (catchment 2) and approximately 66% within the tributary streams that discharge directly to the Manawatū River, noting that the Mangamanaia flows to the Manawatū River upstream of the Manawatū Gorge. A small area (approximately 7.78ha, 4%) will fall into the catchment of the Pohangina River which in turn flows to the Manawatū River.

(d) Earthworks volumes comprise:

(i) bulk structural cut to structural fill of approximately 4,600,000m^3; and

(ii) cut to waste, disposal of surplus material (undercut and unsuitable) of approximately 1,200,000m^3.

(e) Additional earthwork volumes associated with site establishment will be generated in discrete areas within the footprint of works to create access, yards and establish ESC measures (referred to as "**Establishment Works**" and described further below at paragraph 31). The Accommodation Works drawings in the **Drawing Set, Volume III (Drawings TAT-3-DG-C-3601 to TAT-3-DG-C-3616)** illustrate the indicative extent of such works.

24. The Project will include new bridge crossings of the Manawatū River (BR02) and the Mangamanaia Stream (BR07), an Eco Bridge that spans an existing wetland area and a tributary stream (BR03), and a major culvert at Ch. 7840 that will convey a significant catchment flow under the Alignment (CU-08).

Construction zones

25. For construction planning purposes and to effectively manage works, the Project Area is divided into four zones. The zones, which approximately follow cut and fill boundaries across the Project Area and reflect staffing and operational requirements, are as follows:

Table A.1: Indicative Construction Zones

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
Start Station	2840	3900	7100	9565
Finish Station	3900	7100	9565	13800
Cuts	1 - 7	8 - 10	11 - 16	17 - 27

	Zone 1	Zone 2	Zone 3	Zone 4
Fills	1 - 6	7 - 10	10 - 13	14 - 19
Discharge Catchments	Manawatū River; Stream 8A.	Manawatū River; Stream 7A; Stream 7B; Stream 9; Stream 6A	Stream 5A; Stream 5B; Stream 4A.	Stream 3A; Stream 3B; Stream 2A; Stream 2B; Stream 2C: Stream 1A; Stream 1B.

26. Each zone will have a Zone Manager (who will liaise directly with the Environmental Management Team described above at paragraph 18 and below at paragraph 60), Project Engineer, Site Engineer, Site Supervisor and Foreman. The zone management approach allows the Project to be broken down into manageable sizes, for overall construction and environmental management. In addition, an Earthworks Manager will have overall responsibility for all earthworks operations across all zones. The ESC management aspects are covered below in this report and in detail in the ESCP and the ESCMP.

27. The Project Engineer will have direct day to day responsibility for the operation and maintenance of the earthworks and ESC within their zone and will be supported and advised by the Environmental Management Team.

28. The Environmental Management Team will design the ESC (through the development of the SSESCPs) and advise during the construction of the devices with specific responsibility for the installation of the "hardware" (i.e. decants) and chemical treatment systems. The Environmental Management Team will have responsibility for the operation and maintenance of the chemical treatment systems and manage the ESC monitoring and auditing.

Construction stages

29. The high-level construction programme has indicated that earthworks will be required over four years. The areas to be worked in each year will vary based on construction programming, and progressive and permanent stabilisation.

30. The table below provides an estimate of the average "open area" per season based on the current construction programme. "Open area" refers to worked area and assumes that the balance of the Project Area will be in a stabilised state. **Table A.2** includes the average area that will be open during that season.

Table A.2: Average Estimated Annual Earthworks Areas.

	Earthworks Year 1	Earthworks Year 2	Earthworks Year 3	Earthworks Year 4
Average estimated open area (ha)	60	80	65	30

31. The key construction stages associated with a large infrastructure project comprise:

(a) Preparatory works – Initial works to enable Establishment Works and Construction Works such as site surveys and investigations, monitoring set-up and some land disturbance.

(b) Establishment Works – Progressively opening up the site including, for example, constructing and/or widening access tracks to provide access for construction of sediment control areas; followed by vegetation clearance, stream diversions, and construction yards.[2]

(c) Construction phase: early works - Many gullies will require early works to establish upper catchment and stream diversions, followed by initial filling to allow for the installation of cross culverts before the commencement of "bulk" earthworks. In addition, the realigned Te Āpiti Wind Farm access tracks will be constructed prior to commencing the main Alignment works in specific catchments.

(d) Construction phase: main works - Ground improvement, culvert installations, bulk earthworks (including cut and fill activities), drainage installation, bridge construction, pavements and surfacing, reinstatement of site following the completion of construction, landscaping, installation of permanent road furniture and ancillary works.

32. From an ESC perspective, the proposed construction methodology and sequence is a practical approach for carrying out the bulk earthworks required for the Project. This incorporates consideration of water management methodologies and ESC implementation.

33. The construction staging above provides a general sequence of works and has informed the preparation of this assessment, the ESCP, the Concept ESC Drawings and the example SSESCPs.

[2] Authorisation for Access Track 1 and the Eastern Access Track are being sought under separate resource consent applications for Enabling Works. The purpose of those tracks is to provide access into the Alignment from outside the designation area.

34. Detailed ESC methodologies and associated details will be confirmed within the final SSESCPs which will be developed by the Project team and provided to Horizons for certification prior to associated construction works.

BACKGROUND

35. The Transport Agency has separately given notices of its requirement for three designations for the Project ("**NoRs**"), and these NoRs are currently under appeal. I understand that the Transport Agency will ask the Environment Court, as part of those appeals, to modify the NoRs to provide for the Northern Alignment on which the Alliance's concept design is based.

36. I have familiarised myself with the technical assessments previously prepared by the Transport Agency in support of the NoRs in relation to ESC, including:

    (a) Part C: Section 10 of the AEE for the NoRs (Construction of the Project); and

    (b) Statement of evidence of Andrew Mark Whaley (Project Design) on behalf of the Transport Agency, 8 March 2019

    (c) Section 42A Technical Evidence: Construction and Earthworks by Gregor McLean, undated; and

    (d) Section 42A Technical Evidence Addendum: Construction and Earthworks by Gregor McLean, 4 April 2019.

37. In particular, I have had regard to the Transport Agency's proposed conditions for the designations, agreed by the parties to the appeals on the NoRs and lodged with the Environment Court in October 2019 ("**Designation Conditions**"), which include the following Condition 15:

    All erosion and sediment control measures must be designed, constructed and maintained in accordance with Auckland Council GD05 "Erosion and Sediment Control Guide for Land Disturbing Activities in the Auckland Region", June 2016 (GD05) or any subsequent revisions of that document unless:

    (i) land disturbance and associated discharges are permitted by a rule(s) in the One Plan; or

    (ii) the erosion and sediment control measures for the Project are designed, constructed and maintained in accordance with resource consent(s) granted by the Manawatū Whanganui Regional Council.

38. I note that it is the resource consent conditions that will directly manage potential water quality and ecological effects and are the conditions that are most relevant to ESC. Therefore, my consideration of Designation Condition 15 has been limited to ensuring that the recommended management and mitigation strategies and resource consent conditions do not conflict with it. In summary, they cannot, as not only does Designation Condition 15 require the implementation of the Auckland Council GD05 guideline, upon which this ESC Assessment is based, but Designation Condition 15 defers to any future resource consent(s) that control the ESC measures for the Project. I therefore make no further comment on Designation Condition 15.

EXISTING ENVIRONMENT

Topography

39. The Alignment will cross the southern end of the Ruahine Range. Key topographic elements are the Manawatū River, which is crossed at the western end and into which all sub-catchments flow, the variably steep to moderate hill country and plateau of the crossing, and the flat land where the Alignment connects to the existing SH3 west of Woodville.

40. While the Alignment will follow ridges and the plateau to the greatest extent practicable and for the most part will be constructed within grazed farmland, it will cross multiple deeply incised gullies that contain remnant or regenerating native vegetation and areas of exotic scrub.

Geomorphology and soils

41. The geomorphological setting and soils of the Alignment are described by **Mr Cheng** as:[3]

> "*strongly controlled by the tectonic setting of the lower North Island, with the Ruahine Range and the Tararua Range (to the south) forming part of the North Island Axial Ranges. The geological and seismological setting of the area is highly complex*."

42. Geology is mainly papa sandstone/siltstone/mudstone and alluvial gravel and silts with some shallow colluvium, with the soils of the Alignment described as follows:[4]

- *Alluvium:*

[3] Geotechnical Design Technical Memorandum, Appendix A to the DCR (Volume II), Section 2
[4] Geotechnical Design Technical Memorandum, Appendix A to the DCR (Volume II), Section 2.2.

        - *Clayey silts, silty clays, fine to coarse sandy gravels. Mixture of well-rounded gravels and medium well sorted sands. The alluvial deposits are variable. The upper near surface layers are more cohesive.*
        - *Typically encountered at the western end to CH 3600 (Manawatū River) and at the eastern end from CH 12600 to CH 13800.*
    - *Conglomerate:*
        - *Rounded greywacke gravels (10- 50mm). Clasts are matrix supported to clast supported.*
        - *Fines (clay and silt) 5% to 25%, sands up to 40%, gravels 50% to 75%.*
        - *Typically encountered from CH 3900 to CH 4000, and CH 5500 to CH 6900.*
    - *Mudstone:*
        - *Typically, interbedded sandstone/siltstone/mudstone.*
        - *Grading expected to be similar to overburden soils (refer below).*
        - *Typically encountered from CH 6900 to CH 12600.*
    - *Overburden:*
        - *Residually weathered mudstones/sandstone: Typically clays, silts and sandy silts (however will be variable).*
        - *Fines (clays and silts) 50% to 90%, sands 10% to 50%, gravels <1%.*
        - *Typically encountered from CH 3900 to CH 12600, typically at the upper 1m to 3m.*

Rainfall

43. **Dr McConchie** [5] has provided a detailed analysis of the existing and design rainfall depths across a range of frequencies for the Alignment. The mean annual rainfall is in the order of 1200-1300mm and the design depths are within a range that is consistent with the adoption of the ESC management approach described and assessed in this report.

[5] Design Rainfall Analysis and Recommendations (Appendix D.1 of Technical Assessment D).

Freshwater environment

44. Descriptions of the freshwater receiving environments of the Project are provided by **Ms Quinn**[6] and **Mr Hamill**[7], and are adopted herein.

45. The Manawatū River and nine of its sub-catchments will be potentially affected by sediment laden discharges during the construction phases of the Project, as shown in the Waterways and Catchments Overview Plan (**Drawing TAT-3-DG-E-4100 A in Volume III**). Note Catchment 9 discharges to the Pohangina River which in turn discharges to the Manawatū River.

Existing water quality

46. As outlined in **Mr Hamill**'s water quality assessment, baseline water quality monitoring was undertaken to measure water clarity, turbidity, total suspended solids ("**TSS**"), aluminium and pH during wet and dry conditions. Aquatic macroinvertebrate and deposited sediment were also monitored.

47. The baseline monitoring found that most sites had relatively low visual clarity, moderately high turbidity, and high deposited sediments, with the exception of Catchment 7, which had a relatively low proportion of fine sediment on the stream bed.

Existing freshwater ecological values

48. **Ms Quinn**'s freshwater ecology assessment describes the ecological function of the streams within each of the nine catchments based on macroinvertebrate, fish and stream ecological valuation ("**SEV**") data. Based on Ms Quinn's report, the Manawatū River, part of the Mangamania (Sub-catchment 2C) and Catchments 5, 6 and 7 are considered to have high ecological value. The other parts of Mangamanaia (Catchment 2), Catchments 3 and 4 have moderate ecological value and Catchments 1 and 8 have low value. Catchment 9 is also considered to have high ecological value, but the areas in which works are being undertaken are low value and the area of works draining to that catchment is small.

49. In areas of highly agricultural land use and at a more localised level, the stream reaches are of lesser quality and show signs of degradation through stock access and fragmented riparian margins. Most of the streams within the Project Area have evidence of fine sediment deposition, which has altered the naturally hard bottom substrates of the streams.

[6] Freshwater Ecological Assessment (Technical Assessment H).
[7] Water Quality Assessment (Technical Assessment C).

METHODOLOGY

50. This ESC Assessment covers the following:

    (a) overall Project design to avoid and minimise effects;

    (b) erosion and sedimentation processes;

    (c) ESC management;

    (d) monitoring;

    (e) sediment yield assessment;

    (f) statutory considerations;

    (g) assessment of sediment effects; and

    (h) conclusions.

OVERALL PROJECT DESIGN TO AVOID AND MINIMISE EFFECTS

51. As described in the DCR, determining the Alignment has taken account of a number of environmental, social and economic factors. I note in particular that re-locating the Alignment to the north and along the top of the QEII Open Space Covenant gullies has provided an easier topography for the installation and management of ESC measures in those locations. I also note that the Eco Bridge (BR03) will avoid the need for bulk earthworks within the wetland and immediate surrounds at that location. That will also reduce risk and complexity in terms of implementing ESC measures adjacent to that sensitive ecological environment.

EROSION AND SEDIMENTATION PROCESSES

52. 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. The amount of sediment generated through erosion 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 (referred to as "open areas").

53. Sedimentation occurs when these soil particles are deposited. This occurs when runoff velocities become low enough for sediments to fall out of suspension. With the exception of filter socks and filter bags, sediment

retention devices act as low velocity depositional environments by holding water back long enough for sediments to fall out of suspension.

54. The following terms represent the key aspects of ESC:

    (a) Sediment generation – the process whereby erosion dislodges and mobilises soil particles. It is influenced by slope gradient, slope length, soils, rainfall, surface condition and erosion control factors; and

    (b) Sediment yield – the amount of sediment that leaves the site and enters the receiving environment.

55. The purpose of ESC is to minimise sediment yield so as to appropriately limit off-site water quality and ecological effects during the earthworks phase of a project. Erosion control and sediment control must be implemented together to achieve these outcomes.

56. Erosion control is based on the practical prevention of dislodging and mobilising sediment 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.

57. Sediment control refers to management of the sediment after it has been generated. It is inevitable that sediment will be generated through land disturbance activities even with industry 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.

58. Reducing erosion will have the direct effect of reducing sediment generation and the sediment load carried in runoff. This improves the efficiency of sediment control devices and reduces the maintenance frequency required for those devices.

59. The overall effectiveness of the ESC management measures will have a direct effect on the sediment yield that discharges from the site and into the receiving environment.

ESC MANAGEMENT

60. The Project Environmental Management Team structure is described in the ESCP and is shown in **Figure A.1** below, comprising the Environmental Manager, supported by an Environmental Technical Specialist, Environmental Coordinator, Environmental Supervisor, ESC Foremen and ESC Labourers. The ESC measures will be supervised by the Environmental Manager together with the Earthworks Manager.

61. The Environmental Manager will be responsible for ensuring that the SSESCPs are prepared in accordance with the GD05 and the ESCP.

62. The Earthworks Manager will have overall responsibility of ensuring that the SSESCPs are complied with in terms of site operations. The installation and management of the devices will be undertaken by Zone Project Engineers with ESC technical support from the ESC Foremen and Labourers, under the direction of the Environmental Supervisor and management of the Environmental Manager.

63. A current and approved copy of all the SSESCPs will be on site and a copy will be held with the relevant Construction Zone Managers at all times.

64. The Environmental Technical Specialist will prepare SSESCPs and provide all technical specialist input into ESC management.

65. The Environmental Supervisor will maintain daily on-the-ground supervision of the ESC measures across the Project, supported by the ESC Foremen and Labourers, and construction teams.

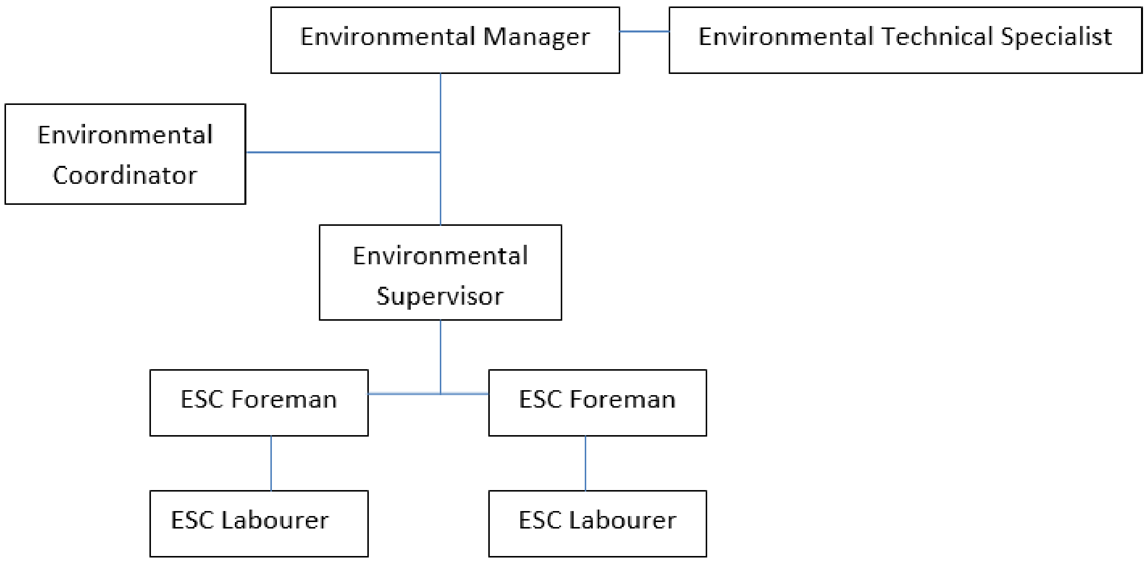

Figure A.1: Project Environmental Management Team structure

Best practice ESC

66. Consistent with Designation Condition 15, all ESC measures will be designed, constructed and maintained in accordance with GD05. This guideline is currently regarded as industry best practice. It will be adopted throughout the Project's works and, for the reasons discussed herein and in supporting specialist assessments, is considered to minimise potential adverse sediment related effects in the receiving environments.

67. The Transport Agency has demonstrated a successful track record with respect to ESC associated with large infrastructure projects and the implementation and maintenance of GD05 and similar compliant controls and methodologies in challenging terrain[8]. This is typically based on an overarching ESC framework, provided through an ESCP coupled with SSESCPs or equivalent plans which focus on the management of specific sites and activities throughout the Project construction phase. This approach enables specific areas of high construction complexity to be identified, staged and successfully managed. The Project does not present any unique challenges and I anticipate that a high standard of ESC can be achieved, consistent with other projects.

Overall ESC objectives

68. As a minimum standard, all construction works will be undertaken in accordance with GD05 to:

(a) minimise the potential for sediment generation and sediment yield while maximising the effectiveness of ESC measures associated with earthworks; and

(b) take all reasonable steps to avoid or minimise potential adverse effects on freshwater environments within or beyond the Project Area that may arise from the discharge of sediment during the construction of the Project.

Key ESC management principles

69. ESC measures will be undertaken and implemented with a hierarchy and priority order as follows:

(a) Erosion control will be provided in all circumstances by minimising sediment generation through a range of structural (physical) measures and non-structural (methodologies and construction sequencing) measures.

(b) Sediment control will be implemented for all sediment laden discharges, primarily by chemically treated SRPs, which will be rationalised within the Project Area to ensure they are fully utilised, centralised, effective and do not create unnecessary earthworks in themselves.

70. The overarching ESC management framework is provided in the ESCP. All ESC methods will meet the minimum criteria of the GD05 Guidelines. In the unusual circumstance where some variation to the GD05 approach is identified

[8] For example: the Puhoi to Warkworth and Huntly Bypass Projects.

as the best option for a specific area or activity, that variation will be subject to the approval of Horizons through the relevant SSESCP.

71. The development of SSESCPs, in accordance with the direction and principles of GD05 and the ESCP, will allow for future flexibility and practicality of approach to ESC and will allow the ability to adapt appropriately to changing conditions.

72. Progressive and rapid stabilisation of disturbed areas using mulch, aggregate and geotextiles will be on-going during the construction phase. Temporary stabilisation will apply particularly with respect to stockpiles, ground improvement locations where topsoil is removed, concentrated flow paths and batter establishment. Permanent stabilisation will be carried out in accordance with the final design parameters and is likely to comprise establishing vegetation (e.g. topsoil and planting), placing mulch and exposed rock surfaces.

73. Stabilisation will need to be appropriate to the soil type, geology and time of year with the intent of achieving at least 80% vegetative cover or other non-erodible surface. Stabilisation is designed for both rainfall and wind erosion control (dust minimisation) and will be progressively implemented.

74. All SRPs and DEBs will be chemically treated. A Chemical Analysis and Reactivity Test[9] (**CART**) has been completed that reports on bench testing undertaken for a range of soil samples taken throughout the Alignment. The CART confirms the effectiveness of chemical treatment for those soils and informs the ESC design and assessment of effects. A CTMP has been prepared that provides a management framework for the implementation of chemical treatment within the Project Area. A schedule within the CTMP will be progressively updated as bench testing is undertaken throughout the Project works. The ongoing bench testing will establish the dose rate and set-up details for the dosing systems within each SSESCP catchment.

75. Stream works will be undertaken in a manner that recognises the higher risk of this activity, from a sediment generation and discharge perspective, and the sensitivity of the receiving environments. Works within active stream channels and any associated works will be undertaken in a 'dry' environment. This will be based upon diversion of flows around the area of works or undertaking construction 'off–line'. Consideration will also be given to peak fish spawning and fish migration periods (if relevant) under the instruction of the Project

[9] Refer to Appendix 1.A of the CTMP, which is Appendix 1 of the ESCP in Volume II.

Ecologist - Freshwater, during which time stream works will be carefully managed or avoided.

76. Monitoring and management of all ESC measures will be undertaken by the Project's experienced Environmental Management and Construction Management Teams and will be extensive and proactive. Environmental management and ESC will form a key component of all construction planning. This monitoring and management are the key factors that will determine the construction environmental success of the Project.

Site specific erosion and sediment control development

77. The inter-relationship between the ESC management documents is provided in **Figure A.2** below.

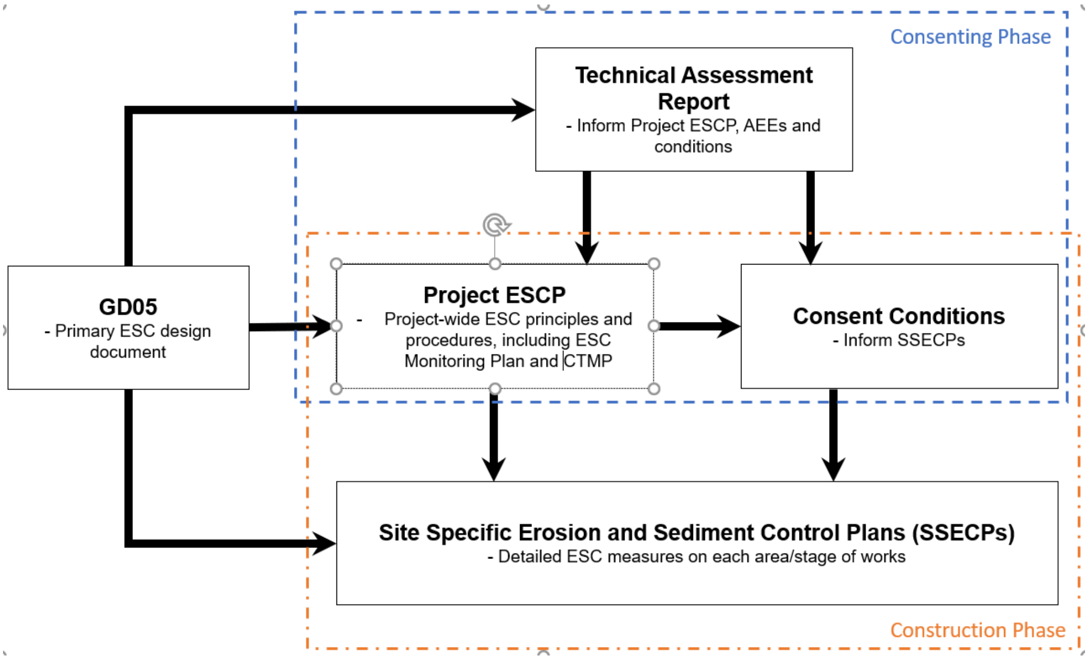

Figure A.2: ESC management document structure

78. Prior to earthworks (or stream works) commencing at a given location, a detailed SSESCP will be prepared and submitted to Horizons for certification against the conditions, GD05 and the ESCP. The SSESCPs will be prepared in accordance with GD05 and specific consent conditions and will be informed by the principles of the ESCP. The SSESCPs will enable specific construction constraints and opportunities to be incorporated into the ESC design for the works at that location. Consistent with the adoption of this approach in other projects, it will allow for enhanced outcomes and the opportunity for implementing innovative practices, particularly in sensitive locations.

79. The SSESCPs will be succinct and focussed technical documents and will include drawings that will detail the ESC measures of that area.

80. The SSESCPs will take account of the following factors:

(a) the specific construction activity to be undertaken;

(b) the area and volume of earthworks, and/or the nature of the stream works at specific locations, and identification of the downstream receiving environment;

(c) the locations of all earthworks and/or stream works;

(d) methods for managing construction water effects for specific activities;

(e) the duration of the earthworks and/or stream works;

(f) the time of the year that the stream works are to be undertaken, and where applicable, the measures to be implemented to respond to any heightened weather risks at that time;

(g) stabilisation methods and timing to reduce the open area at key locations to assist with a reduction in sediment generation; and

(h) chemical treatment (flocculation) at SRPs and DEBs.

MONITORING

81. An ESCMP has been developed for the Project and is included in the ESCP. It provides a programme and methodology to ensure that ESC measures have been designed, installed and managed in accordance with the ESC management structure described above, and to monitor the effectiveness of ESC for the duration of the construction phases of the Project.

82. Environmental compliance and performance will be achieved through appropriate location, design, installation, as-built certification, maintenance, and monitoring of ESC devices. ESC management in this context is not restricted to physical structures but also includes work practices and methodologies.

83. As-built certification of devices is a critical element of effective site management. As-built checklists and/or drawings will be prepared for all controls to ensure that they have been installed as designed. Works within the catchment of an ESC device will not commence until the as-built document for the device (or devices) has been certified by a suitably experienced ESC practitioner.

84. Regular monitoring will be undertaken by the Environmental Management Team and ESC Foremen to ensure ESC devices are operating as designed and are

maintained in accordance with guidelines and consent conditions. This monitoring underpins the successful implementation of the ESC management system, to achieve the anticipated environmental outcomes and ensure compliance with the resource consent conditions. This monitoring includes pre- and post-rainfall checks and maintenance and is considered "business as usual".

85. The monitoring will also provide continual feedback to ensure successful ESC performance and early detection of activities or problems that have the potential to result in an adverse environmental effect.

86. The frequency of the device monitoring will vary throughout the year and reflect areas of changing activity and risk within the Project Area. During active construction in a given area, the monitoring will be undertaken daily as well and pre- and post-rainfall events. Monitoring will report any repairs or issues that need to be addressed and the timeframe for completion of those actions.

87. The regular monitoring will be supported by monitoring of the chemical treatment systems, weather, rainfall trigger events, and will include wet weather responses and contingencies.

Weather forecasting, recording and responses

88. Weather forecast monitoring will form an important part of the Project's ESC management and will initiate pre-rain inspections as well as inform the timing of higher risk activities such as stream works.

89. Monitoring weather forecasts is also a critical tool in managing weather events and prompt site preparation for the event. The Environmental Management Team will utilise readily available forecast methodologies including metvuw.com and metservice.com. Forecast maps will be reviewed daily and assessed for periods of wet weather as required.

90. Rainfall will be recorded by two telemetered rainfall monitoring stations that will be installed on site to provide real-time continuous rainfall intensity and volume data. That real-time data will be available via a range of platforms including mobile phone apps. Email and text notifications will be programmed to ensure relevant staff, including the Environmental Management Team, are alerted when rainfall trigger events occur.

91. Recorded rainfall will be compared to forecasts to assist more accurate rainfall prediction as the Project progresses.

92. Where more significant rainfall events are forecast, including trigger events (discussed below), additional site inspections will be undertaken by the Environmental Management Team to ensure all ESC measures are fully operational and identify any additional measures that could be installed, such as additional sediment sumps or contour drains.

Chemical treatment monitoring

93. A core part of chemical treatment management is monitoring to check that the systems are all working as anticipated and to provide information to facilitate ongoing management of the chemical treatment systems.

94. Monitoring and maintenance of the chemical treatment systems will be undertaken in accordance with the CTMP and the ESCMP. It will include a visual inspection of the chemical treatment system at least weekly and pre- and post-rainfall, and inspection of clarity of impounded water and discharges from SRPs and DEBs. All components of the treatment system will be checked, including the catch trays, inlet and outlet hoses, and chemical discharge location. The pH of the discharge will be checked to ensure that it is within the 5.5 to 8.5 range.

95. As required, the tanks will be drained of rainwater and the chemical reservoir will be refilled. The chemicals will be securely stored in drums contained in the sheds or in Immediate Bulk Containers ("**IBCs**") adjacent to the sheds, depending on the treatment system used at any given site.

96. Where clarity is less than anticipated a suitably experienced ESC specialist will be contacted and the ESC system for that device will be reviewed. This may include re-testing of soils and adjusting the dose rate.

Trigger event monitoring

97. The objective of this monitoring is to understand the performance of the Project’s ESC measures through a range of larger (but still relatively frequent) storm events, using turbidity as a proxy for pond efficiency.

98. Consistent with other projects of comparable scale, topography and/or location, two rainfall response triggers will be adopted; being 15mm in one hour, and 25mm in 24 hours. These triggers have been adopted as intensities and durations above which a range of more significant outflows are likely to occur from SRPs and DEBs. They have been applied to the management of

earthworks sites in various locations,[10] including several large development areas around Silverdale and Hobsonville within the greater Auckland area.

99. When a trigger event is forecast, a pre-rain inspection will be undertaken by the Environmental Management Team in conjunction with the Construction Management Team. The purpose of the inspection will be to ensure that the site is fully prepared for the higher intensity and/or duration rainfall event and identify any additional measures that could be adopted to further minimise the risk of sediment discharges.

100. When a rainfall trigger occurs, Environmental Management Team members and key Construction Management Team members will be notified via the telemetered rainfall monitoring stations and site monitoring will be initiated. Inflow and outflow turbidity will be recorded manually at each SRP and DEB that is discharging (subject to health and safety restrictions such as limitations on night access). This data will be used to confirm SRP and DEB performance, including trends or variability between devices. This will in turn allow ongoing identification of issues and adjustments to maximise performance across the site.

101. The inflow and outflow turbidity of two SRPs (to be selected in consultation with Horizons) will be continuously measured using automated sensors, with the data uploaded to a global data network. Turbidity will also be manually recorded at those ponds during or immediately after a trigger event.

102. The automated devices will provide real time information to the Environmental Management and Construction Management Teams for all rainfall that results in inflow and outflow from those SRPs and will assist in validating pond performance. It will also be correlated with the manual turbidity recording to ensure accuracy.

Turbidity vs Total Suspended Solids

103. In the past five years turbidity and Total Suspended Solids ("**TSS**") have been adopted as parameters for monitoring the performance of consented ESC systems within various earthworks projects. In some cases, TSS has also been applied as a performance standard.

104. Since 2017 I have been a member of the SSEL team that has been managing the rainfall trigger response monitoring of the Milldale development north of Silverdale, Auckland, and two sites at Hobsonville Point, West Auckland.[11] I am

[10] For example, the Puhoi to Warkworth Motorway; Mt Messenger Bypass; and Turitea Wind Farm Projects
[11] 10 Scott Road and 20 Scott Road.

also very familiar with the rainfall response monitoring requirements of the Puhoi to Warkworth motorway project[12] ("**P2WK**") currently under construction by the Northern Express Group, which I refer to in more detail below.

105. Through the above experience and my experience in ESC design and implementation on roading projects throughout New Zealand generally, I have identified significant limitations in the suitability of TSS as a monitoring requirement or performance standard for earthworks sites. I explain this further below.

106. In determining what I consider to be the most appropriate monitoring parameters for the Project, I have reflected on my experience of such systems, and have had particular regard to the document titled ‘Recommended Water Quality Standards for the Manawatu-Wanganui Region: Technical Report to Support Policy Development’, June 2007 (Water Quality Standards Technical Report) that informed the development of the Horizons Regional Council One Plan ("**Water Quality Standards Technical Report**").

107. The Water Quality Standards Technical Report considered three parameters that are commonly used to determine sediments within water; being turbidity and TSS (which I have noted above) and visual clarity. Clarity and turbidity can be measured on site in real time (site and time specific), whereas accurate TSS reporting requires sampling and analysis in a laboratory, normally taking 2 – 4 days to be reported.

108. The Water Quality Standards Technical Report recommended that standards relating to changes in water clarity were adopted as representative of the sediment in the water column, and also as the recommended default indicator of the risk of fine sediment deposition. The One Plan's Schedule D: Surface Water Quality Targets is based on the percentage change of water clarity.

109. Water quality monitoring is being undertaken on numerous large projects as listed above at paragraph 104 and including the Transmission Gully project north of Wellington. The monitoring systems vary between projects but include manual and automated recording of turbidity, manual recording of clarity, and manual and automated sampling of TSS which is later analysed in a laboratory.

110. From an ESC management perspective, the most immediate data is the most useful in terms of understanding the performance of SRPs and DEBs, identifying issues and responding to any performance issues promptly. Delays in obtaining site performance information is of little use in terms of site

[12] Ara Tūhono Pūhoi to Wellsford Road of National Significance, Pūhoi to Warkworth Section.

management, as sites and weather are dynamic and need to be responded to with immediacy. Accordingly, I favour turbidity and clarity as the most relevant and useful measures for the Project and do not support TSS sampling/monitoring requirement. I expand on the reasons for this below:

(a) Typically, there is a delay of several days between sampling and reporting on TSS by the analysing laboratory. That delay exceeds the response time necessary in the event of downstream effects that may be identified during site monitoring.

(b) The assumed sediment retention efficiencies of control devices are averages. Sediment concentration of the discharge from a SRP or DEB varies throughout a storm. Unless a TSS limit is set very high, it is likely that the TSS will exceed an arbitrary threshold at some stage of a storm but will on average be within the envelope of acceptable effects anticipated for the Project.

(c) Turbidity and clarity are well understood proxies for water quality within sediment control devices and can be easily measured in real time along with the other site inspection and management activities that will occur during or immediately after a storm event.

(d) Turbidity and clarity are better aligned with the approach to water quality taken in the One Plan and the supporting Water Quality Standards Technical Report.

111. Turbidity and clarity have been recommended as the most time- and cost-effective means of monitoring the Project's ESC performance. While turbidity and clarity monitoring does not allow an accurate assessment of sediment loads discharging from the site, it does provide immediate data, either through the automated sampling system or manual recording. This immediacy allows rapid response to any significant fluctuations in performance, and to the overall ongoing monitoring and management of the ESC system across the Project. Correlation between the continuous sampling of two SRPs with the manual sampling of all SRPs will allow a refinement of the understanding of the overall performance of the devices across the Project.

112. Notwithstanding the above, I reiterate that the most important element of ensuring that sediment effects are acceptably minimised is the diligent implementation of the ESCP, SSESCPs and supporting systems through staff training and device design, construction, maintenance and reporting.

Monitoring supports and informs those fundamental aspects of site management.

113. Finally, I consider it important to note that a Project-specific assessment of sediment-related effects has been undertaken based on the proposed GD05 compliant ESC management system and the estimates of sediment yield derived on that basis. As a result, the imposition of GD05 standard controls and associated management plans is the appropriate performance standard for the Project. A separate TSS performance standard is, in my opinion, unnecessary and unrelated to the likely effects of the Project.

Monitoring of receiving environments

114. Monitoring of receiving environments will be undertaken in accordance with the Aquatic Ecology Monitoring Protocol ("**AEMP**"), which is part of the Freshwater Ecology Management Plan, which is provided at Section 10 of the Ecology Management Plan (“**EMP”**) (in **Volume VII**) and is not addressed further in this report.

115. Pre-construction baseline monitoring of water quality, ecology and deposited sediment will determine the variable characteristics of those parameters across a range of stream states and seasons. During construction, routine monitoring of those parameters will be undertaken, and event-based monitoring will also be carried out in relation to specific issues should they occur on site.

116. The ESCMP cross-references to the AEMP for detail on event-based receiving environment monitoring should specified non-compliances occur that result in sediment discharges to streams.

Reporting

117. Details of the proposed reporting are provided in the ESCMP. An internal audit will be undertaken by an Environmental Manager or Environmental Technical Specialist at least weekly.

118. Actions will be loaded into the Environmental Management System and Work Instructions with details and timeframes to be issued by the Environmental Manager or Environmental Technical Specialist to the relevant ESC Foreman, with specific actions and closeout timeframes. The ESC Foreman will report completion of those actions and the Environmental Manager or Environmental Technical Specialist will inspect the works and close-out the items in the Management System.

119. For programmed Council inspections, a member of the Environmental Management Team will accompany the Council inspector in all audits. Usually a member of the Construction Management Team will also be present.

120. As for internal audits, all ESC maintenance actions identified by the Council inspector will be recorded by the Environmental Manager or Environmental Technical Specialist, who will issue Work Instructions with details and timeframes to the ESC Foreman in accordance with the Council's instruction. The ESC Foreman will report back on the completion of those actions to the Environmental Manager or Environmental Technical Specialist, who will inspect and confirm the compliance of the works; and email confirmation to the Council inspector.

121. Following a rainfall trigger event, a report will be provided to Horizons within 10 working days of the event which will include a summary of the performance of the SRPs, DEBs and overall ESC system observed during the rainfall event.

Annual report

122. An annual report containing monitoring results and an assessment of discharge performance will be provided to Horizons by June 30 of each year. This report will contain a summary of the results of all monitoring within that period, discussion on device performance, and a summary of responses to rainfall triggers.

SEDIMENT YIELD ASSESSMENT

Approaches to estimating sediment yield

123. For consenting purposes, the requirement to estimate sediment yield from earthworks projects has varied throughout New Zealand. The practice of forecasting likely sediment yield from construction sites began in the Auckland region during the 1990s and was used to assist in the design of ESC measures within a project. This approach allowed potential variability in sedimentation yield across a site to be identified as well as informing the construction industry of the indicative volumes of sediment that could be generated and discharged from earthworks if not appropriately managed.

124. With respect to more recent Transport Agency projects, various approaches to estimating sediment yield and associated effects have been applied. These have ranged from assessments based on typical earthworks catchments within a project area, to project-wide modelling and estimates using various assessment tools.

125. The most commonly used estimating tool has been the USLE. More sophisticated modelling tools have also been used, including the Groundwater Loading Effects of Agricultural Management Systems ("**GLEAMS**") model, which was applied to the P2WK project, in conjunction with the USLE.

126. P2WK in particular invested significant time and cost to derive estimates of sediment yield to a high degree of resolution, albeit subject to the uncertainty associated with the assumption inputs applied to the modelling.

127. For the recently consented Mt Messenger Bypass, the Transport Agency project team adopted the estimated hill country annual sediment yield value derived from the P2WK modelling, based on an assumption of sufficiently similar soil types and topography.

128. For the Huntly Bypass, the Transport Agency project team provided USLE calculations for three typical SRP catchments within the alignment (being steep (2.17ha), moderate (2.1ha) and low gradient (2.08ha)) as representative of the project without any further project-wide extrapolation.

129. Waikato Regional Council has confirmed that no sediment yield assessment was undertaken for the Hamilton Bypass.[13]

130. The Transport Agency and its contractors, including Fulton Hogan and HEB Construction, now have a breadth of experience in the performance of ESC management tools derived from monitoring undertaken on various roading projects.[14] This includes the data derived from P2WK as discussed below. This information allows greater confidence in estimating sediment yields and confirming the relevance (or otherwise) of the available prediction tools.

Utilising data from comparable and relevant projects

131. Given the information now available from other projects, it is now possible to utilise actual data to refine estimates of sediment yield during the construction of the Project. The P2WK provides a relevant study in this regard for the following reasons:

(a) The Project and P2WK have comparable characteristics including:

(i) hill country terrain;

(ii) mix of soil, regolith and rock to be exposed during construction, albeit that the Project soils have a higher coarse fraction;

[13] Personal comment by Tammy Valler, Waikato Regional Council Land Development Resource Use Officer overseeing the Hamilton Bypass Project.
[14] Including P2WK, Northern Gateway, SH16-SH18, SH16 Te Atatu and Lincoln Road, Waikato Expressway, Tauranga Eastern Link, East Taupo Arterial, Transmission Gully, Christchurch Southern and Northern Motorways.

(iii) steep, relatively short freshwater streams passing through and discharging downstream of the site;

(iv) similar construction methodology and period; and

(v) the same ESC design, construction and maintenance standard, based on GD05.

(b) The P2WK project included extensive modelling of sediment yield using GLEAMS and USLE.[15]

(c) The P2WK consent conditions have required continuous monitoring and rainfall event-based reporting of SRP performance, which is available to validate the efficacy of the ESC measures employed. Monitoring includes automated flow and sediment sampling on selected devices, and manual sediment sampling.

(d) The P2WK consent conditions have also required the preparation of quarterly reports on the performance of the ESC measures and overview of effects (if any) on freshwater and marine receiving environments.

(e) Based on the NIWA online High Intensity Rainfall Design System ("**HIRDS**"), typical rainfall intensities and volumes for P2WK are higher than for the Project.

P2WK – predicted and actual sediment yield and ESC performance

132. A Construction Water Assessment Report ("**CWAR**") was prepared in the consenting phase of the P2WK project and provides an assessment of the anticipated construction water effects of that project. The CWAR provided an assessment of anticipated sediment yields for the two primary catchments across site – Mahurangi catchment and Puhoi catchment. Separate sediment yields were established for the Mahurangi hill country and Mahurangi flat country. Sediment yields within the CWAR were calculated using the USLE and a GLEAMS model. These predicted a construction sediment yield of 49.1t/ha/year for the hill country and 22.9t/ha/year for the flat country.

133. Once construction commenced a suite of monitoring requirements were triggered by the resource consent conditions. The conditions require an analysis of trends in SRP performance in the monitoring data by comparison with previous periods, different ponds and with the original estimated sediment yield calculation for each stage of works (as extrapolated from the yield predicted in the CWAR for the relevant focus areas).

[15] Further North, August 2013 'Construction Water Assessment Report'.

134. The calculated sediment yield is used to determine the estimated tonne of sediment discharged during each stage of work. The CWAR, in comparison, assumes that the maximum area is open for the entirety of the works and the controls in place are operating at capacity.

135. Manual grab samples are taken at the outlet of all SRPs and selected DEBs during or immediately after rainfall events which exceed 25mm/24-hour period and/or 15mm/hour. The samples are sent to an accredited laboratory to determine the TSS concentrations. Over time a sediment yield is calculated using the TSS results and by estimating the quantity of water discharged from site via sediment controls. The sediment discharge (total sediment yield per hectare per year) is extrapolated using the results from each rainfall event and quarterly period.

136. Correspondingly, automated sampling of inflow and outflow TSS has been recorded at four sediment control devices and used to derive pond efficiencies.

137. The validity of a sediment yield derived from manual grab samples is limited as manual grab samples do not capture fluctuations in outlet TSS over the duration of the storm event. To address this the automated monitoring data from the four sediment controls has also been analysed to determine the difference between the outlet TSS at the time manual grab samples were taken and the peak outlet TSS measured during the storm. The worst case mean ratio has been applied as a "multiplier" to the manual grab sample sediment yields calculated.

138. **Table A.3** below provides the output of the analysis undertaken. It shows that the original values of sediment yield derived from the GLEAMS modelling and USLE calculations (49.1 t/ha/yr for hill country and 22.9 t/ha/yr for flat country) significantly overestimated the actual yields being produced by the P2WK project.

Table A.3: Sediment yield ranges

Catchment	Lowest range (best case) (t/ha/yr)	Highest range (worst case) (t/ha/yr)	Predicted (t/ha/yr)
Mahurangi flat country	0.41	6.18	22.9
Mahurangi hill country	2.99	16.9	49.1
Puhoi hill country	1.05	17.61	49.1

139. This conservativism is compounded by the fact that the original values used in the P2WK assessment were found to result in adverse effects of an acceptable level within receiving streams and the sensitive estuarine receiving environment

of the Puhoi Estuary and Mahurangi Harbour, across a range of storms up to the 50 year ARI event.[16]

140. The data recorded to date at P2WK has shown that the predictive tools used to estimate sediment yield for that project significantly overestimated the yields in fact discharged from the site following implementation of industry best practice ESC measures.

141. Therefore, in my opinion, the USLE outputs derived specifically for this Project will not underestimate sediment yield and can be relied on by various experts to inform their assessment of likely downstream sediment-related effects of the Project.

Estimate of sediment yield for the Project

142. Eight USLE estimates of sediment yield have been undertaken for typical SRP catchments within the Project Area, located across the steeper land, central plateau and flat land. These are provided in **Appendix A.1**.

143. Applying an estimate that best reflects the topography or soil type of given section of earthworks within the Project, USLE estimates have been applied to the footprint of earthworks within the main stream systems crossing the Alignment (including sub-catchments) to derive estimates of sediment load in tonnes from the Project for one year, being the first year of works within each given area. A full spreadsheet of the derived values is provided in **Appendix A.1**.

144. The first year is the most significant, where initial opening of land will expose the steepest initial slopes. After that, many cuts will progressively expose less-erodible rock materials, and initial slope gradients exposed at the start of works within a location will ease as embankment and carriageway gradients are formed, and stabilised. Hence, the initial few months of work in each location will have the highest potential for sediment generation.

145. To the greatest extent practicable, earthworks areas, including gully fills, will be treated by chemically treated SRPs, which are the most efficient sediment retention device, followed by chemically treated DEBs. Areas treated by silt

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[16] *Final Report and Decision of the Board of Inquiry into the Ara Tūhono - Pūhoi to Wellsford Road of National Significance: Pūhoi to Warkworth Section Volume 1 of 4: Final Report and Decision*; at [470] to [472]: The Board found that the possible sedimentation effects on the Mahurangi Harbour and Pūhoi Estuary would be considered somewhat more than minor in an RMA context, but not of a scale or nature that would prevent the project proceeding. In respect of the Mahurangi Harbour, the Board found that possible sedimentation effects would be negligible, minor or slightly more than minor in an RMA context, but again not of a scale or nature that would prevent the project proceeding.

fences will be minimised as far as practicable and will not be a significant component of the overall treatment system within any area of works.

146. The USLE values reported above include the following assumptions:

(a) Soil composition of 40% clay, 50% silt, and 10% sand. This is considered to be a conservative assumption for the site on the basis of available data, as the site comprises soils with a significant coarser fraction. Nor does it reflect that in some areas the Alignment will cut into sandstone and siltstone and will comprise rock cut batters and benches. Those areas are predicted to have lower sediment generation potential than the soil composition used in the USLE analysis.

(b) The catchment will be fully exposed for the full eight months of the earthworks period each year and is assumed to have a bare rough surface with a corresponding sediment delivery ratio of 50% which is the value typically adopted for that scenario. Again, this is a conservative assumption as in practice some areas will be progressively stabilised, such as cut and fill batters, and completed areas.

(c) Assumed no use of contour drains. However, in practice contour drains will be implemented to break up flow path lengths and correspondingly reduce sediment generation.

(d) Assumed 95% average treatment efficiency for chemically treated SRPs.[17] This value has been generally accepted for Transport Agency and other earthworks projects throughout New Zealand and is supported by real-time automated monitoring of ponds within various projects.[18] As detailed in the CART, bench testing of soils from the Project Area has shown a good response to chemical treatment.

(e) Assumed 80% average treatment efficiency for chemically treated DEBs, based on GD05 design.

147. **Table A.4** below provides a summary of the estimated sediment yields (t/ha/yr) and loads (t/yr) derived from the USLE estimates for each stream system that crosses the Alignment, as identified in **Appendix A.1**. It presents the sediment yield estimated for the initial year of works in each SRP catchment based on the footprint of earthworks within the catchment, a corresponding estimate of sediment yield for that same footprint under the existing land use, and presents the additional load that will result from the earthworks over that period. In addition, the existing land use estimated sediment yields have been

[17] Auckland Regional Council Technical Publication 227 – *'The Use of Flocculants and Coagulants to Aid the Settlement of Suspended Sediment in Earthworks Runoff : Trials, Methodology and Design, June 2004'*
[18] P2WK; Milldale Development Stages 1 and 2

extrapolated to include the area of each catchment that lies beyond the works footprint. This is discussed later.

Table A.4: Estimated sediment yields and loads for the Project for the initial phase of works at each sector

Stream	Earthworks area total (ha)	Indicative USLE Catchment	Sediment yield earthworks (t/ha/yr)	Sediment load earthworks (t/yr)	Sediment yield from existing land within earthworks footprint (t/ha/yr) (using same indicative USLE catchment)	Sediment load from existing land within Project earthworks footprint (t/yr)	Sediment load difference: earthworks minus existing (t/yr)	Stream Catchment (ha)	Catchment Sediment Load Before (t/yr) (based on USLE existing land assumptions)	Catchment sediment load during earthworks (t/yr) (catchment sediment load + sediment load difference)	Catchment sediment load increase (t/yr)	% increase catchment sediment load	Catchment sediment yield Before earthworks t/ha/yr	Catchment sediment yield during Earthworks t/ha/yr	Earthworks area as % of catchment
Catchment 1	2.56	13050 (2B)	0.15	0.38	0.05	0.13	0.26	114	5.70	5.96	0.26	4%	0.05	0.052	2.2%
2A/2B - east of bridge **	11.72	13050 (2B)	0.15	1.76	0.05	0.59	1.17	431							
2C - west of bridge **	44.12	SRP 12400	1.8	79.42	0.6	26.47	52.94	1227							
2A & 2C d/s of 2e	55.84			81.17		27.06	54.12	1658	758	812	54	7%	0.46	0.49	3.4%
Catchment 2 (d/s 2E)	55.84			81.17		27.06	54.12	1658	758	812	54	7%	0.46	0.49	3.4%
3A	6.59	SRP 10000	5.2	34.27	1.7	11.20	23.07	47	80	103	23	29%	1.70	2.19	14%
3B	7.64	SRP 10000 (3B)	5.2	39.73	1.7	12.99	26.74	18	31	57	27	87%	1.70	3.19	42%
3A d/s 3B confluence	14.23		5.2	74.00	1.7	24.19	49.81	65	111	160	50	45%	1.70	2.47	22%
Catchment 3	14.23			74.00	1.70	24.19	49.81	123	209	259	50	24%	1.70	2.10	12%
4A CH 7550-9150 (low gradient) **	33.76	SRP 8800	1	33.76	0.3	10.13	23.63	122							
4A CH 9150-9750 (steeper gradient) **	11.25	SRP / DEB 9500	5	56.25	1.1	12.38	43.88	207							
Catchment 4 at SH	45.01			90.01		22.50	67.51	329	264	332	68	26%	0.8	1.01	14%
Catchment 4	45.01			90.01		22.50	67.51	412	331	399	68	20%	0.8	0.97	11%
5A	6.69	SRP 7000 (5B)	3.6	24.08	1.2	8.03	16.06	52	62	78	16	26%	1.20	1.5	13%
5B	20.75	SRP 7000	3.6	74.70	1.2	24.90	49.80	52	62	112	50	80%	1.20	2.2	40%
5A & 5B d/s of confluence	27.44		3.6	98.78	1.2	32.93	65.86	104	125	191	66	53%	1.20	1.8	26%
Catchment 5	27.44			98.78		32.93	65.86	120	144	210	66	46%	1.20	1.75	23%
6A d/s 6B confluence	7.10	SRP 7000 (5B)	3.6	25.56	1.2	8.52	17.04	29	34.8	52	17	49%	1.20	1.79	24%
Catchment 6	7.10	SRP 7000 (5B)	3.6	25.56	1.2	8.52	17.04	95	114	131	17	15%	1.20	1.38	7.5%
7A d/s 7B/7C confluence	29.31	SRP 7000 (5B)	3.6	105.52	1.2	35.17	70.34	100	120	190	70	59%	1.20	1.9	29%
Catchment 7	29.31	SRP 7000 (5B)	3.6	105.52	1.2	35.17	70.34	110	132	202	70	53%	1.20	1.84	27%
Catchment 8	5.34	13050 (2B)	0.15	0.80	0.05	0.27	0.53	101	5.05	6	1	11%	0.05	0.06	5.3%
Catchment 9	7.78	SRP 7000 (5B)	3.6	28.01	1.2	9.34	18.67	220	264	283	19	7%	1.20	1.28	3.5%
Total (Manawatu River)	194.61			504.23		160.10	344.13		1895.90	2240.03	344.13	18%			

** These lines were used for calculating loads at a sub-catchment scale. Sediment yields for catchments before earthworks were estimated using the USLE calculations applied to earthwork sites and scaled by catchment area.
USLE calculations for 'steep' or 'low' gradient sites were weighted in accordance with the estimated proportion of area as steep or low gradient in the relevant catchment.

STATUTORY CONSIDERATIONS

148. The relevant statutory provisions are provided in **Appendix D, Volume I**. A full rule assessment is provided in **Section 4 of the AEE** (supported by the Rule Assessment Table in **Appendix C of Volume I**), and an objective and policy assessment in **Section 8 of the AEE**. However, the provisions particularly relevant to land disturbance and ancillary discharge of sediment are set out below.

149. Land disturbance and the associated discharge of sediment during construction of the Project requires resource consent under Chapter 13 (Land Use Activities and Indigenous Biological Diversity) of the One Plan if undertaken adjacent to water bodies, in Hill Country Erosion Management Areas, or a rare habitat, threatened habitat or at-risk habitat.

150. It is assumed that all properties that are traversed by the Project will, at least in part, be located in a Hill Country Erosion Management Area (which is defined as 'any area of land with a pre-existing slope of 20 degrees or greater' under the One Plan) and will therefore require resource consent as a restricted discretionary activity pursuant to Rule 13-6.

151. The matters of discretion under Rule 13-6 relate to:

(a) the location, nature, scale, timing and duration of the activity;

(b) effects of the activity and associated sediment run-off on soil conservation, surface water quality and aquatic ecology and the methods to be taken to avoid, remedy or mitigate them;

(c) the requirement to provide an ESCP, the content of and standard to which the ESCP must be prepared, the implementation of the ESCP, and the timing of when it must be prepared and submitted;

(d) the provision of greater setback distances from water bodies than those specified under condition (b) to provide greater protection to a water body if required;

(e) the extent of non-compliance with the water quality target for visual clarity set out in Schedule E;

(f) the duration of consent;

(g) the review of consent conditions;

(h) compliance monitoring;

(i) the matters in Policy 14-9 (which relates to the NPSFM).

152. These matters of discretion are addressed in the Assessment of Effects (paragraphs 156 to 162 below) with the exception of aquatic ecology effects (which are addressed by **Ms Quinn** in her report); and water quality targets (which are addressed by **Mr Hamill** in his report).

153. In addition, some elements of the work require resource consent as a discretionary activity pursuant to Rule 13-7, which covers land disturbance and vegetation clearance in a Hill Country Erosion Management Area and within 10m of a watercourse, (but not in a rare, at risk or threatened habitat).

154. Some land disturbance and vegetation clearance will be required within rare or threatened Schedule F habitats which require land use consent pursuant to Rule 13-9. Impacts of land disturbance and vegetation clearance on rare or threatened habitat (as shown on the Terrestrial Ecosystems Plans, **Drawings TAT-3-DG-E-4131 to TAT-3-DG-E-4137** in the **Drawing Set, Volume III**) are addressed in detail in **Mr Baber's** Terrestrial Ecology Assessment (**Technical Assessment F, Volume V**).

155. Objectives and policies relevant to land disturbance are contained in Chapter 4 of the One Plan (which is part of the Regional Policy Statement); and Chapter 13 (which is part of the Regional Plan).

ASSESSMENT OF EFFECTS

Positive effects

156. The primary positive effects of the Project are transport related. The ESC methodology discussed in this report is mitigation for potential sediment-related adverse effects during construction.

Adverse effects

157. The sediment loads predicted are only a portion of the overall load that will enter a given stream during a rain event, as the Alignment is only a proportion of the entire catchment of each stream system. While most of the stream catchments include forest and regenerating forest, all include significant areas of pastoral farming. Sediment sources within those catchments will include sediment laden runoff from existing pasture, forest, stream bank and stream bed erosion, land slips, farm tracking and sundry other sources.

158. The potential adverse effects of the predicted sediment yield from the Project on water quality and the freshwater receiving environments are assessed and reported on by **Mr Hamill** and **Ms Quinn** in their reports. I rely on those assessments to support my conclusion that with the implementation of the best-

practice ESC methodology that I have described above, construction of the Project is unlikely to result in significant sediment-related adverse effects downstream of the Project Area.

159. The right-hand column of **Table A.4** provides the total area of each stream system and illustrates the proportion of each catchment that the earthworks will comprise. Sediment will continue to be generated from the existing land uses within those catchments, via surface water runoff, stream bank and bed erosion, and potential periodic land slips. This ongoing erosion is evident in the state of those streams, as reported by Mr Hamill and Ms Quinn.

160. In my opinion, ESC management can be achieved, operated and maintained to a high standard in accordance with the expectations of the GD05, which is New Zealand's current best practice ESC Guideline and specifications document to minimise the sediment related effects of the Project. This conclusion is based on my personal experience of roading and other projects that have implemented the same standard of ESC practice, the Project emphasis on proactive monitoring to maintain the performance of all ESC devices, the conservatism in USLE estimates, and the relative proportion of each catchment in relation to the earthworks footprint as I have noted above in **Table A.4**.

161. Post-construction sediment effects are likely to be limited to potential erosion at the outfalls of stormwater reticulation and treatment devices. I am satisfied that such outfalls will incorporate design elements that will appropriately minimise such effects and would expect that outcome to be imposed as a performance standard through consent conditions.

162. For completeness I note that Mr Chilton's Air Quality Assessment concludes that the potential dust effects during construction can be mitigated to acceptable levels, based on a range of site management procedures and monitoring he has recommended. Those procedures and monitoring requirements have been incorporated into the Dust Management Procedure provided as Appendix 3 of the ESCP (**Volume VII**), which has been reviewed by Mr Chilton.

CONCLUSION AND RECOMMENDATIONS

163. A best-practice ESC management system will be implemented for the duration of the earthworks phase of the Project.

164. Suitably qualified ESC practitioners experienced in large scale roading projects in similar terrain as the Project will design and supervise the construction and management of ESC measures throughout the Project.

165. Comprehensive monitoring of the ESC management system will be undertaken to ensure that it performs as anticipated, and that off-site impacts remain within the envelope of effects predicted and assessed through this ESC Assessment.

166. Subject to the ongoing implementation of the proposed ESC management system, the sediment yield from the Project will be appropriately minimised and will not result in significant adverse downstream effects.

167. The resource consent conditions should include the requirement to implement and monitor the ESC measures in accordance with GD05 as described through the ESCP and its Appendices, which include the Concept ESC Drawings, example SSESCPs and ESCMP.

Campbell Stewart

DISCLAIMERS

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

We understand and agree that our client will submit this report in support of an application for resource consent and that Horizons Regional Council as the consenting authority will use this report for the purpose of assessing that application.

We understand and agree that this report will be used by Horizons Regional Council in undertaking its regulatory functions in connection with resource consent applications associated with the Project.

APPENDIX A.1: USLE SUMMARY TABLE AND WORK SHEETS

Universal Soil Loss Equation (USLE) Calculations Summary Table

USLE calculations taken from representative catchments across the Project Area.

Device (SRP = Sediment Retention Pond; DEB = Decanting Earth Bund)

Earthworks footprint sediment yield estimate analysis.

Device and Chainage	**Contributing catchment (ha) of sediment retention device**	**USLE estimated sediment load (t/yr)**	**USLE estimated sediment yield (t/ha /yr)**	**USLE estimated sediment load pre-earthworks (same contributing catchment assuming no earthworks) (t/yr)**	**USLE estimated sediment yield pre-earthworks (t/ha/yr)**
SRP 7000	3	10.9	3.6	3.7	1.2
SRP 8800	4	3.9	1	1.3	0.3
SRP 9300	1.6	6.2	4.8	2.1	1.3
SRP 9500 DEB 9500	1.3	6.5	5	1.8	1.1
SRP 10000	2.6	13.6	5.2	4.5	1.7
SRP 12050	4	3.9	1	1.3	0.3
SRP 12400	2	3.6	1.8	1.2	0.6
SRP 13050	2	0.3	0.15	0.1	0.05

USLE Work Sheets

Universal Soil Loss Equation

Pre-earthworks

Universal Soil Loss Equation **Project** Te Ahu a Turanga **Total Estimated Sediment Yield** 3.7368
Total Catchment Area (ha) 3.00

Sub-Catchment	R	K	LS (USLE Parameters)	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 7000	58	0.34	6.30	0.02	1.00	3.00	1.00	7.4736	0.50	0%	3.7368

Sub-Catchment Description		SRP ch 7000	*Subcatchments must be named to be included in summary*	
Exposed Catchment Area (ha)			Exposed Area (ha)	3.000
Average Catchment Slope (%)			Average Slope %	16.00
				3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		6.30	150
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	LS (USLE Parameters)	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 7000	58	0.34	6.30	0.02	1.00	3.00	1.00	7.47	0.50	0%	3.7368

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 1.3282
Total Catchment Area (ha) 4.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 8800	58	0.34	1.68	0.02	1.00	4.00	1.00	2.6565	0.50	0%	1.3282

Sub-Catchment Description		SRP ch 8800	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	4.000	
Average Catchment Slope (%)			Average Slope %	5.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		1.68	300
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 8800	58	0.34	1.68	0.02	1.00	4.00	1.00	2.66	0.50	0%	1.3282

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 1.2305
Total Catchment Area (ha) 2.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 12400	58	0.34	3.11	0.02	1.00	2.00	1.00	2.4611	0.50	0%	1.2305

Sub-Catchment Description		SRP ch 12400	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.000	
Average Catchment Slope (%)			Average Slope %	8.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.11	300
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 12400	58	0.34	3.11	0.02	1.00	2.00	1.00	2.46	0.50	0%	1.2305

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 1.3282
Total Catchment Area (ha) 4.00

Sub-Catchment	R	K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
	USLE Parameters										
SRP ch 12050	58	0.34	1.68	0.02	1.00	4.00	1.00	2.6565	0.50	0%	1.3282

Sub-Catchment Description		SRP ch 12050	*Subcatchments must be named to be included in summary*	
Exposed Catchment Area (ha)		Exposed Area (ha)	4.000	
Average Catchment Slope (%)		Average Slope %	5.00	3
Rainfall Erosion index	R	Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil / 40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length	1.68	300
Ground Cover Factor	C	Pasture - undisturbed	0.02	
Roughness Factor	P	Pasture - undisturbed	1.00	
Sediment Delivery Ratio			0.50	
Sediment Control Measure Efficiency		pre earthworks	0%	
Duration of Exposure		Months	12.00	

Catchment details	R	K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
	USLE Parameters										
SRP ch 12050	58	0.34	1.68	0.02	1.00	4.00	1.00	2.66	0.50	0%	1.3282

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 0.1104
Total Catchment Area (ha) 2.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 13050	58	0.34	0.28	0.02	1.00	2.00	1.00	0.2209	0.50	0%	0.1104

Sub-Catchment Description		SRP ch 13050	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.000	
Average Catchment Slope (%)			Average Slope %	1.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		0.28	400
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 13050	58	0.34	0.28	0.02	1.00	2.00	1.00	0.22	0.50	0%	0.1104

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 2.1217
Total Catchment Area (ha) 1.60

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9300	58	0.34	6.71	0.02	1.00	1.60	1.00	4.2433	0.50	0%	2.1217

Sub-Catchment Description		SRP ch 9300	*Subcatchments must be named to be included in summary*	
Exposed Catchment Area (ha)		Exposed Area (ha)	1.600	
Average Catchment Slope (%)		Average Slope %	16.00	3
Rainfall Erosion index	R	Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil; 40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length	6.71	170
Ground Cover Factor	C	Pasture - undisturbed	0.02	
Roughness Factor	P	Pasture - undisturbed	1.00	
Sediment Delivery Ratio			0.50	
Sediment Control Measure Efficiency		pre earthworks	0%	
Duration of Exposure		Months	12.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9300	58	0.34	6.71	0.02	1.00	1.60	1.00	4.24	0.50	0%	2.1217

Universal Soil Loss Equation **Project** Te Ahu a Turanga **Total Estimated Sediment Yield** 1.8395
SRP / DEB ch 9500 **Total Catchment Area (ha)** 1.00

Sub-Catchmen	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9500	58	0.34	7.87	0.02	1.00	1.00	1.00	3.1128	0.50	0%	1.5564
DEB ch 9500	58	0.34	3.41	0.02	1.00	0.30	1.00	0.4044	0.70	0%	0.2831

Sub-Catchment Descriptio SRP ch 9500 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	1.000	
Average Catchment Slope (%)			Average Slope %	18.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		7.87	160
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment de	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9500	58	0.34	7.87	0.02	1.00	1.00	1.00	3.11	0.50	0%	1.5564

Sub-Catchment Descriptio DEB ch 9500 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	0.300	
Average Catchment Slope (%)			Average Slope %	18.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.41	30
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment det	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
DEB ch 9500	58	0.34	3.41	0.02	1.00	0.30	1.00	0.40	0.70	0%	0.2831

Sub-Catchment Descriptio		DEB ch 9500	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	0.300	
Average Catchment Slope (%)			Average Slope %	18.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.41	30
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment det	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
DEB ch 9500	58	0.34	3.41	0.02	1.00	0.30	1.00	0.40	0.70	0%	0.2831

Sub-Catchment Descriptio			*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)		
Average Catchment Slope (%)			Average Slope %	18.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.41	30
Ground Cover Factor	C		Mulch - on subsoil (3 month only	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only	1.00	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			T-Bar Decanting Earth Bund - Chemical Treatment	80%	
Duration of Exposure			Months	4.00	

Catchment det	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
0	58	0.34	3.41	0.15	1.00	0.00	0.33	0.00	0.70	80%	0.0000

Universal Soil Loss Equation **Project** Te Ahu a Turanga **Total Estimated Sediment Yield** 1.8395

SRP / DEB ch 9500 **Total Catchment Area (ha)** 1.30

Sub-Catchment	R	K	LS (USLE Parameters)	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9500	58	0.34	7.87	0.02	1.00	1.00	1.00	3.1128	0.50	0%	1.5564
DEB ch 9500	58	0.34	3.41	0.02	1.00	0.30	1.00	0.4044	0.70	0%	0.2831

Sub-Catchment Description: SRP ch 9500 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	1.000	
Average Catchment Slope (%)			Average Slope %	18.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		7.87	160
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	LS (USLE Parameters)	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9500	58	0.34	7.87	0.02	1.00	1.00	1.00	3.11	0.50	0%	1.5564

Sub-Catchment Description: DEB ch 9500 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	0.300	
Average Catchment Slope (%)			Average Slope %	18.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.41	30
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	LS (USLE Parameters)	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
DEB ch 9500	58	0.34	3.41	0.02	1.00	0.30	1.00	0.40	0.70	0%	0.2831

Universal Soil Loss Equation | **Project** Te Ahu a Turanga | **Total Estimated Sediment Yield** 4.5243
SRP Ch 1000 | **Total Catchment Area (ha)** 2.60

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP Ch 10000	58	0.34	8.80	0.02	1.00	2.60	1.00	9.0487	0.50	0%	4.5243

Sub-Catchment Description		SRP Ch 10000	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.600	
Average Catchment Slope (%)			Average Slope %	18.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		8.80	200
Ground Cover Factor	C		Pasture - undisturbed	0.02	
Roughness Factor	P		Pasture - undisturbed	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			pre earthworks	0%	
Duration of Exposure			Months	12.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP Ch 10000	58	0.34	8.80	0.02	1.00	2.60	1.00	9.05	0.50	0%	4.5243

Universal Soil Loss Equation Earthworks

Universal Soil Loss Equation **Project** Te Ahu a Turanga **Total Estimated Sediment Yield** 10.8944
Total Catchment Area (ha) 3.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 7000	58	0.61	6.30	1.00	0.90	3.00	0.67	402.2561	0.50	95%	10.0564
SRP ch 7000	58	0.61	6.30	0.15	1.00	3.00	0.33	33.5213	0.50	95%	0.8380

Sub-Catchment Description SRP ch 7000 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	3.000	
Average Catchment Slope (%)			Average Slope %	16.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		6.30	150
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 7000	58	0.61	6.30	1.00	0.90	3.00	0.67	402.26	0.50	95%	10.0564

Sub-Catchment Description SRP ch 7000 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	3.000	
Average Catchment Slope (%)			Average Slope %	16.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		6.30	150
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield

SRP ch 7000	58	0.61	6.30	0.15	1.00	3.00	0.33	33.52	0.50	95%	0.8380

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 3.8724
Total Catchment Area (ha) 4.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 8800	58	0.61	1.68	1.00	0.90	4.00	0.67	142.9819	0.50	95%	3.5745
SRP ch 8800	58	0.61	1.68	0.15	1.00	4.00	0.33	11.9152	0.50	95%	0.2979

Sub-Catchment Description: SRP ch 8800 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	4.000	
Average Catchment Slope (%)			Average Slope %	5.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		1.68	300
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 8800	58	0.61	1.68	1.00	0.90	4.00	0.67	142.98	0.50	95%	3.5745

Sub-Catchment Description: SRP ch 8800 *Subcatchments must be named to be included in summary*

Exposed Catchment Area (ha)			Exposed Area (ha)	4.000	
Average Catchment Slope (%)			Average Slope %	5.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		1.68	300
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 8800	58	0.61	1.68	0.15	1.00	4.00	0.33	11.92	0.50	95%	0.2979

Universal Soil Loss Equation **Project** Te Ahu a Turanga **Total Estimated Sediment Yield** 3.5876
Total Catchment Area (ha) 2.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 12400	58	0.61	3.11	1.00	0.90	2.00	0.67	132.4637	0.50	95%	3.3116
SRP ch 12400	58	0.61	3.11	0.15	1.00	2.00	0.33	11.0386	0.50	95%	0.2760

Sub-Catchment Description		SRP ch 12400	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.000	
Average Catchment Slope (%)			Average Slope %	8.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		3.11	300
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 12400	58	0.61	3.11	1.00	0.90	2.00	0.67	132.46	0.50	95%	3.3116

Sub-Catchment Description		SRP ch 12400	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.000	
Average Catchment Slope (%)			Average Slope %	8.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		3.11	300
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRP ch 12400	58	0.61	3.11	0.15	1.00	2.00	0.33	11.04	0.50	95%	0.2760

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 3.8724
Total Catchment Area (ha) 4.00

Sub-Catchment	R	K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
	USLE Parameters										
SRP ch 12050	58	0.61	1.68	1.00	0.90	4.00	0.67	142.9819	0.50	95%	3.5745
SRP ch 12050	58	0.61	1.68	0.15	1.00	4.00	0.33	11.9152	0.50	95%	0.2979

Sub-Catchment Description		SRP ch 12050	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	4.000	
Average Catchment Slope (%)			Average Slope %	5.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		1.68	300
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
	USLE Parameters										
SRP ch 12050	58	0.61	1.68	1.00	0.90	4.00	0.67	142.98	0.50	95%	3.5745

Sub-Catchment Description		SRP ch 12050	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	4.000	
Average Catchment Slope (%)			Average Slope %	5.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		1.68	300
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
	USLE Parameters										
SRP ch 12050	58	0.61	1.68	0.15	1.00	4.00	0.33	11.92	0.50	95%	0.2979

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 0.3120
Total Catchment Area (ha) 2.00

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 13050	58	0.61	0.28	1.00	0.90	2.00	0.67	11.8872	0.50	95%	0.2972
SRP ch 13050	58	0.61	0.28	0.15	1.00	2.00	0.33	0.9906	0.30	95%	0.0149

Sub-Catchment Description		SRP ch 13050	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.000	
Average Catchment Slope (%)			Average Slope %	1.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		0.28	400
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 13050	58	0.61	0.28	1.00	0.90	2.00	0.67	11.89	0.50	95%	0.2972

Sub-Catchment Description		SRP ch 13050	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.000	
Average Catchment Slope (%)			Average Slope %	1.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		0.28	400
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.30	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generated	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 13050	58	0.61	0.28	0.15	1.00	2.00	0.33	0.99	0.30	95%	0.0149

Universal Soil Loss Equation **Project** Te Ahu a Turanga

Total Estimated Sediment Yield 6.1856
Total Catchment Area (ha) 1.60

Sub-Catchment	R	USLE Parameters K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9300	58	0.61	6.71	1.00	0.90	1.60	0.67	228.3916	0.50	95%	5.7098
SRP ch 9300	58	0.61	6.71	0.15	1.00	1.60	0.33	19.0326	0.50	95%	0.4758

Sub-Catchment Description		SRP ch 9300	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	1.600	
Average Catchment Slope (%)			Average Slope %	16.00	3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		6.71	170
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	USLE Parameters K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9300	58	0.61	6.71	1.00	0.90	1.60	0.67	228.39	0.50	95%	5.7098

Sub-Catchment Description		SRP ch 9300	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	1.600	
Average Catchment Slope (%)			Average Slope %	16.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		6.71	170
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	USLE Parameters K	LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9300	58	0.61	6.71	0.15	1.00	1.60	0.33	19.03	0.50	95%	0.4758

Universal Soil Loss Equation **Project** Te Ahu a Turanga **Total Estimated Sediment Yield** 6.5172

SRP / DEB ch 9500 **Total Catchment Area (ha)** 1.30

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9500	58	0.61	7.87	1.00	0.90	1.00	0.67	167.5440	0.50	95%	4.1886
SRP ch 9500	58	0.61	7.87	0.15	1.00	1.00	0.33	13.9620	0.70	95%	0.4887
DEB ch 9500	58	0.34	3.41	1.00	0.90	0.30	0.67	12.1311	0.70	80%	1.6984
DEB ch 9500	58	0.34	3.41	0.15	1.00	0.30	0.33	1.0109	0.70	80%	0.1415

Sub-Catchment Description		SRP ch 9500	*Subcatchments must be named to be included in summary*			
Exposed Catchment Area (ha)				Exposed Area (ha)	1.000	
Average Catchment Slope (%)				Average Slope %	18.00	3
Rainfall Erosion index	R			Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil		40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length			7.87	160
Ground Cover Factor	C			Bare Soil - rough irregular surface	1.00	
Roughness Factor	P			Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio					0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment		95%	
Duration of Exposure				Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
SRP ch 9500	58	0.61	7.87	1.00	0.90	1.00	0.67	167.54	0.50	95%	4.1886

Sub-Catchment Description		SRP ch 9500	*Subcatchments must be named to be included in summary*			
Exposed Catchment Area (ha)				Exposed Area (ha)	1.000	
Average Catchment Slope (%)				Average Slope %	18.00	
Rainfall Erosion index	R			Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil		40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length			7.87	160
Ground Cover Factor	C			Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P			Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio					0.70	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment		95%	
Duration of Exposure				Months	4.00	

Estimated Sediment Sediment Estimated

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Sediment Generate	Delivery Ratio	Control Efficiency	Sediment Yield
SRP ch 9500	58	0.61	7.87	0.15	1.00	1.00	0.33	13.96	0.70	95%	0.4887

Sub-Catchment Description		DEB ch 9500	*Subcatchments must be named to be included in summary*	
Exposed Catchment Area (ha)			Exposed Area (ha)	0.300
Average Catchment Slope (%)			Average Slope %	18.00
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.41	30
Ground Cover Factor	C		Bare Soil - rough irregular surfac	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			T-Bar Decanting Earth Bund - Chemical Treatment	80%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
DEB ch 9500	58	0.34	3.41	1.00	0.90	0.30	0.67	12.13	0.70	80%	1.6984

Sub-Catchment Description		DEB ch 9500	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	0.30	
Average Catchment Slope (%)			Average Slope %	18.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Topsoil	40%Clay, 50%Silt, 10%Sand	0.34	
Slope Length and Steepness Factor	LS	User defined Slope length		3.41	30
Ground Cover Factor	C		Mulch - on subsoil (3 month only	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			T-Bar Decanting Earth Bund - Chemical Treatment	80%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency	Estimated Sediment Yield
DEB ch 9500	58	0.34	3.41	0.15	1.00	0.30	0.33	1.01	0.70	80%	0.1415

Universal Soil Loss Equation | **Project** Te Ahu a Turanga | **Total Estimated Sediment Yield** 13.5963

SRP Ch 1000 | **Total Catchment Area (ha)** 2.60

Sub-Catchment	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRPCh 10000	58	0.61	8.80	1.00	0.90	2.60	0.67	487.0316	0.50	95%	12.1758
SRPCh 10000	58	0.61	8.80	0.15	1.00	2.60	0.33	40.5860	0.70	95%	1.4205

Sub-Catchment Description		SRPCh 10000	*Subcatchments must be named to be included in summary*	
Exposed Catchment Area (ha)			Exposed Area (ha)	2.600
Average Catchment Slope (%)			Average Slope %	18.00
				3
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		8.80	200
Ground Cover Factor	C		Bare Soil - rough irregular surface	1.00	
Roughness Factor	P		Bare Soil - rough irregular surface	0.90	
Sediment Delivery Ratio				0.50	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	8.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRPCh 10000	58	0.61	8.80	1.00	0.90	2.60	0.67	487.03	0.50	95%	12.1758

Sub-Catchment Description		SRPCh 10000	*Subcatchments must be named to be included in summary*		
Exposed Catchment Area (ha)			Exposed Area (ha)	2.600	
Average Catchment Slope (%)			Average Slope %	18.00	
Rainfall Erosion index	R		Te Ahu a Turanga	58	*User Defined*
Soil Erodibility Factor	K	Bare Soil	40%Clay, 50%Silt, 10%Sand	0.61	
Slope Length and Steepness Factor	LS	User defined Slope length		8.80	200
Ground Cover Factor	C		Mulch - on subsoil (3 month only)	0.15	
Roughness Factor	P		Mulch - on subsoil (3 month only)	1.00	
Sediment Delivery Ratio				0.70	
Sediment Control Measure Efficiency			Sediment Retention Pond - Chemical Treatment	95%	
Duration of Exposure			Months	4.00	

Catchment details	R	K	USLE Parameters LS	C	P	Area (ha)	Time (years)	Estimated Sediment Generate	Sediment Delivery Ratio	Sediment Control Efficiency (%)	Estimated Sediment Yield
SRPCh 10000	58	0.61	8.80	0.15	1.00	2.60	0.33	40.59	0.70	95%	1.4205