Before a Board of Inquiry
Transmission Gully
Notices of Requirement and Consents

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under:	the Resource Management Act 1991
in the matter of:	Notices of requirement for designations and resource consent applications by the NZ Transport Agency, Porirua City Council and Transpower New Zealand Limited for the Transmission Gully Proposal
between:	**NZ Transport Agency** *Requiring Authority and Applicant*
and:	**Porirua City Council** *Local Authority and Applicant*
and:	**Transpower New Zealand Limited** *Applicant*

Statement of rebuttal evidence of Michelle Kathleen Malcolm (Water Quality) for the NZ Transport Agency and Porirua City Council

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Dated: 27 January 2012

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STATEMENT OF REBUTTAL EVIDENCE OF MICHELLE KATHLEEN MALCOLM FOR THE NZ TRANSPORT AGENCY AND PORIRUA CITY COUNCIL

INTRODUCTION

1 My full name is Michelle Kathleen Malcolm.

2 I have the qualifications and experience set out at paragraphs 2 - 4 of my statement of evidence in chief, dated 22 November 2011 (*EIC*).

3 I repeat the confirmation given in my EIC that I have read, and agree to comply with, the Code of Conduct for Expert Witnesses (Consolidated Practice Note 2011).

4 In this statement of rebuttal evidence, I respond to the evidence of:

4.1 Dr Basher, on behalf of the Director-General of Conservation (*DOC*);

4.2 Mr Handyside, on behalf of DOC; and

4.3 Ms Kettles, on behalf of DOC.

5 I also respond in part to the section 42A report prepared by Dr Murray Hicks (*Section 42A Report)*.[1] I respond to those aspects of the Section 42A Report which relate to the Revised Analysis and additional sensitivity and uncertainty analysis presented below. However, I have not had sufficient time to address all of the matters raised in Dr Hicks report, and will address the remaining issues in my rebuttal evidence in response to the submitters' supplementary evidence. I will also address any issues raised in Mr McLean's report at that time (because I have not seen that report at the time of preparing this evidence).

6 The fact that this rebuttal statement does not respond to every matter raised in the evidence of submitter witnesses within my area of expertise should not be taken as acceptance of the matters raised. Rather, I rely on my EIC and this rebuttal statement to set out my opinion on what I consider to be the key water quality matters for this hearing.

7 For the purposes of this evidence, I will refer to the NZ Transport Agency (*the NZTA*) Project[2] and the Porirua City Council (*PCC*)

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[1] Hicks, D.M., *Transmission Gully Project Peer Review of Sediment Generation and Yield Aspects Prepared for Environmental Protection Authority*, January 2012.

[2] The 'NZTA Project' refers to the construction, operation and maintenance of the Main Alignment and the Kenepuru Link Road by the NZTA.

Project[3] collectively as the "Transmission Gully Project" (and hereafter, *the TGP* or *the Project*).

SUMMARY OF EVIDENCE

8 I have read all of the statements of evidence provided by submitters in relation to my area of expertise. The evidence prepared by the submitters and the Section 42A Report have caused me to reflect on the level of detail in the processes described in Technical Report 15 and my EIC. I have carried out further work to respond to concerns raised. However, neither the evidence nor the Section 42A Report have caused me to depart substantially from the opinions expressed in my EIC and I re-confirm the conclusions reached in my EIC.

9 As a result of matters raised in conferencing in December 2011, and in the evidence of Dr Basher and Mr Handyside, I have carried out a Revised Analysis of my sediment generation predictions. That Revised Analysis is appended to the second Earthworks and Sediment Control Conferencing Statement (dated 20 January 2012) and is described in this rebuttal statement. The Revised Analysis confirms that the calculated sediment generation resulting from construction of the Project presented in Technical Report 15 *(TR15)* (hereafter called the *Assessed Estimate*) is accurate or conservative for most catchments, but under-estimated sediment generation from construction in the Kenepuru catchment (partly because it did not accurately account for the fill sites in that catchment).

10 The Revised Analysis also addresses some of the concerns raised in the Section 42A Report.

11 It was agreed during conferencing on 20 January 2012 that the Revised Estimate provides a better estimation and reduced uncertainty in modified USLE[4] parameters.[5]

12 It was also agreed during conferencing on 20 January 2012 that I should address baseline and construction sediment estimate uncertainties in this rebuttal statement.[6] I have addressed these matters below. There are different types of uncertainties associated with the Revised Estimate, which I have described, and in some instances attempted to quantify. In my view, the assessment provides a reasonable basis for prediction of effects and foundation for other experts to do so, in order to set appropriate conditions. Accordingly, the appropriate focus should be on the conditions as

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3 The 'PCC Project' refers to the construction, operation and maintenance of the Porirua Link Roads (being the Whitby Link Road and the Waitangirua Link Road) by PCC.

4 Universal Soil Loss Equation.

5 Paragraph 8.

6 See paragraph 9 of the Conferencing statement dated 20 January 2012.

the means of managing construction in order to avoid, remedy and/or mitigate effects.

13 I also recommend further amendments to conditions, to respond to concerns raised in evidence. These amendments would reduce the uncertainties associated with open earthworks areas during construction and ensure sediment generation is likely to be similar to that modelled.

REVISED USLE ANALYSIS AND ESTIMATE

Difference between Assessed Analysis and Revised Analysis

14 In response to matters raised in Dr Basher's evidence and conferencing[7], I undertook a more detailed USLE calculation. This Revised Analysis did not just change the SDR[8] to between 0.5 and 0.7 as suggested by Dr Basher. This approach would not have resulted in unrealistic yields due to the conservatism present in other USLE inputs. Accordingly, the Revised Analysis reviewed all USLE inputs. The key aspects of this Revised Analysis are:

14.1 The USLE is applied in detail to the construction areas. The Revised Estimate accounts for the actual Project earthworks area based on the calculated surface area of the design provided by **Mr Edwards[9].** This area takes into account enabling works and stream diversion earthworks coincident with programmed earthworks;

14.2 In the Revised Analysis, the soil erodibility has been altered to reflect the 'K' values[10] for the fill and cut slopes. The cuts take account of the 'K' value for the colluvium or alluvium and account for the proportion of rock in cuts that exceed the depth of soil. The 'K' for the fills accounts for the fill material proposed. Overall, 70% of the available cut material is estimated to be in rock. Separate 'K' values have been calculated for enabling works and haul roads, which are in surface soils, and for stream works. For all stream works the assumption is that the stream flow is diverted around the construction area and construction is therefore carried out "in the dry". The Analysis does not account for erosion caused by stream flows[11];

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[7] Expert Conferencing Joint Report to the Board of Inquiry – Earthworks and Sediment Control Conferencing, 7 and 8 December 2011.

[8] Sediment Delivery Ratio.

[9] An estimate of the sediment yield, scaled by area to represent the same construction area as was assumed for the analysis set out in the AEE, is provided in Table 19 of the Revised Analysis appended to the 20 January 2012 Conferencing Statement.

[10] Soil erodibility value.

[11] The contribution of stream works to sediment yield is further discussed in **Appendix A** to this statement.

14.3 The 'L/S'[12] is altered to reflect the road cross section during construction;

14.4 The SDR is altered to reflect the slope of the construction site between the site of generation and sediment discharge locations. SDR values of 0.5 and 0.7 were used, as suggested by Dr Basher;

14.5 It is unlikely to be possible to chemically treat all the stream works and enabling works. **Mr Gough** advises in his rebuttal evidence that a range of devices will be used including silt fences and earth decanting bunds, and some of these devices may be chemically treated. Also, these may not be the size required to individually meet the required 70% performance standard. The Revised Analysis assumes a 30% removal rate for these areas in the Q2 and Q10 events and this supported by **Mr Gough's** rebuttal evidence[13];

14.6 It was always intended that erosion control be applied to the 'unstabilised' area, and this is described in TR15 as having an assumed treatment efficiency of 75%. In the Revised Analysis it is assumed that cuts and fill batters are benched and progressively stabilised, the haul road is stabilised, and a proportion of other areas are treated with erosion protection with an efficiency of 75%.

15 This Revised Estimate has relied on geological and construction information provided by **Mr Brabhaharan**. In his rebuttal evidence[14] he describes the construction method as follows:

> "*In the steep mountainous to hilly terrain in the Wellington Region, earthworks are typically carried out in small fronts, with excavation of rock using excavators, sometimes assisted by ripping, and transportation of cut materials using dump trucks and placement at fill embankment sites. The work areas are therefore predominantly flat areas where fill is placed, with steep excavation faces in rock or dense alluvium. The hillsides generally remain undisturbed until the time of excavation or fill placement, and cut slopes and fill embankment slopes are hydroseeded or otherwise protected soon after construction of each section of slope...*"

Results of Revised Analysis

16 **Table 1** below shows the results of the Revised Analysis. Because the Revised Estimate has used actual values in place of various assumptions used for the modelling described in TR15, the

[12] Length / slope.

[13] Paragraphs 26-28.

[14] Paragraph 54.

difference between the Revised Estimate and TR15 modelling shows how conservative those assumptions were. Negative percentages indicate conservatism in assessed construction yield compared to the Revised Estimate, whereas positive percentages indicate that the assessed construction yield was non-conservative.

Table 1 Comparison between Assessed and Revised sediment yield

	Assessed Increase (T)		Revised Increase (T)		Conservatism (%)
Catchment	**Q2**	**Q10**	**Q2**	**Q10**	
Kenepuru	40	111	60	168	51
Duck	59	272	28	131	-52
Pauatahanui	16	100	17	106	6
Ration	116	578	105	522	-10
Horokiri	100	546	39	212	-61
Te Puka	502	2549	371	1885	-26

Horokiri

17 The Assessed Analysis in the Horokiri has a conservatism of 61%, when compared to the Revised Estimate. The conservatism in this catchment relates to the quantity of underlying rock.

Te Puka

18 The Assessed Analysis in the Te Puka has a conservatism of 26%, when compared to the Revised Estimate. The conservatism in this catchment relates to the quantity of underlying rock.

Ration

19 The Assessed Analysis estimate in the Ration has a conservatism of 10%, when compared to the Revised Estimate. There are deeper alluvial soils in this section, but there are also significant silty gravel fills. The Revised Estimate accounts for the construction of this section within 9 months, which is the programmed timeframe. For the remainder of the year the earth-worked area is assumed to be stabilised with temporary grass.

20 Additional Harbour modelling has being undertaken to assess the effects in the Harbour of the peak construction year in the Ration. This had not previously been modelled because no construction in the Ration catchment had been programmed for the peak construction year of the Project as a whole. The results of this modelling are discussed in **Dr De Luca's** rebuttal evidence.

Pauatahanui

21 The Assessed Analysis under-estimated sediment yield in the Pauatahanui by 6%, when compared to the Revised Estimate. There are some deep alluvial soils in this section, but there are also significant greywacke rock fills.

22 **Mr Roberts** has advised me that sediment discharged from the Pauatahanui stream and Ration stream is deposited in a similar area of the Harbour. Therefore, the additional Harbour modelling of the peak year in the Ration will also provide information to assess the effects from discharges from the Pauatahanui stream. This is discussed in **Dr De Luca's** rebuttal.

Duck

23 The Assessed Analysis in the Duck has a conservatism of 52%, when compared to the Revised Estimate. There are relatively shallow alluvium soils in this catchment with cuts and fills in greywacke rock. The reduction in area has a significant impact for this catchment, because the modelled section is the Waitangirua Link Road, which has a smaller footprint than the Main Alignment.

24 If the area is scaled to 75m wide to provide for the Main Alignment works in the Duck catchment (rather than the Waitangirua Link Road), then the conservatism changes to 13%.

Kenepuru

25 The Revised Estimate for the Kenepuru is 51% greater than the Assessed Analysis, despite the significant underlying rock in this section. The reason the Revised Estimate is more than the Assessed Analysis, is related to the increase in length slope compared to the baseline length slope. Also, the Assessed Analysis did not specifically account for the fill sites within the Kenepuru (instead, a general allowance for enabling works had been made across the site as a whole). The Revised Estimate allows for 2.2 ha of fill sites open coincident with the peak earthworks on the Main Alignment.

26 Additional Harbour modelling has being undertaken to assess the effects in the Harbour of the peak construction year in the Kenepuru. The results of this increase are discussed by **Dr De Luca**.

QUANTIFYING UNCERTAINTIES IN MODELLING

27 At conferencing on 20 January 2012, it was agreed that the Revised Estimate provides a better estimate and reduced uncertainty in USLE parameters.

28 It was also agreed that baseline and construction sediment estimates have uncertainty, which is inherent in the methodology

and more generally in sediment science. As the conferencing statement records, I agreed to undertake uncertainty analysis as part of my rebuttal evidence.[15]

29 Uncertainties are normal in any sediment modelling process, and this is why modelling is just one of the tools used to help quantify, assess, and manage the effects of sediment on the environment.

30 I have carried out the following analysis in order to determine the level of uncertainty:

30.1 I have undertaken sensitivity analysis to determine the sensitivity of the sediment yield to performance of erosion and sediment control measures. This is set out in **Appendix A** to this evidence, and summarised below. **Appendix A** also contains consideration of the sensitivity of the estimate to enabling works and stream works; and

30.2 I have considered the uncertainty associated with the baseline average annual and event loads. This is set out in **Appendix B** to this evidence, and summarised below.

Sensitivity analysis – construction estimate

31 The following scenarios were modelled in order to test the sensitivity of the sediment yield to performance of erosion and sediment control measures:

31.1 Scenario One: stabilization as with Revised Analysis with more stablization in Kenepuru and Ration, erosion control applied to active areas that is 50% effective, reduced sediment control.

31.2 Scenario Two – Staging control as per the Revised Estimate, erosion control is less effective, no sediment control.

32 Scenario one illustrates the erosion and sediment control philosophy in TR15 which is reflected in the conditions. It provides a suite of erosion and sediment control measures, which when considered working together, significantly reduce the potential sediment yield.

33 **Table 12** in **Appendix A** illustrates the scenario that was assessed. **Table 3** in **Appendix A** shows that a very similar outcome for construction sediment yield is achieved when the sediment control devices do not perform at their optimum, provided erosion protection of the active earthworks area is achieved.

34 Scenario two is not considered a likely scenario because erosion and sediment control measures are an integral part of the Project's construction. Nonetheless it illustrates the importance of erosion

15 See paragraph 9 of the 20 January 2012 conferencing statement.

and sediment control measures in achieving the assessed sediment yields entering the receiving environments.

35 These sensitivity analysis results show that stabilisation before heavy rain events achieves a reduction in sediment yield compared with that calculated in the Revised USLE Analysis. In all catchments, with the exception of Kenepuru, the assessed yields discussed in TR15 are conservative compared with this scenario. In the case of the Kenepuru, the yield is conservative compared with the most recent harbour modelling which modelled an increase of 168 tonnes of sediment as a result of construction. **Dr De Luca** discusses the effect of the increased construction sediment in the Onepoto Arm of the harbour.

36 This analysis demonstrates the importance of erosion and sediment control measures working in conjunction with each other. In this case the lower assumed performance of the sediment ponds is offset by accounting for the deployment of erosion control measures when heavy rain is forecast. The stabilized areas in the Kenepuru and Ration were also increased in this scenario. This is considered to be a more realistic assessment of the proportion of the area that would be stabilised and under erosion control in these catchments.

37 I consider conditions E3(j), E3(k) and E5(l) to be integral to achieving the erosion and sediment control performance that has been assumed for the sediment yield calculations. In my view, any further reduction in uncertainty in the performance of the erosion and sediment control measures is best achieved through the consent conditions.

38 The sensitivity analysis has confirmed my conclusion in my EIC that, assuming the consent conditions are confirmed as proposed, and that the proposed management plan framework is accepted and implemented, it is my opinion that the potential adverse water quality effects can be managed to an acceptable level. The potential ecological effects of the construction discharges are discussed by **Dr Keesing** and **Dr De Luca**

Uncertainty in the average annual baseline

39 The purpose of this uncertainty analysis is to better describe the inherent uncertainty in the estimation of baseline sediment generation and to provide context to the estimates of sediment generation calculated for the Project.

40 Dr Phillip Jordon of SKM[16], with my assistance, has undertaken the uncertainty analysis, which is presented in detail in **Appendix B** to this statement.

41 The overall uncertainty in the suspended sediment yield estimates from each of the catchments is comprised of two components:

41.1 The uncertainty introduced by scaling the estimated yields from the USLE to the yield estimates from the NIWA suspended sediment yield; and

41.2 The inherent uncertainty in the NIWA suspended sediment yield estimates.

42 The uncertainty analysis has quantified that estimated loads from the catchments under existing conditions (with no road) estimated using the approach presented in Technical Report 15 could be between 0.31 and 3.2 times the values presented in the report. By comparison, the SSYE average annual estimates could be between 0.35 and 2.9 times the average annual estimate.

43 I have undertaken a sensitivity analysis that reduces the baseline sediment yield to 2631 t/y, which is based on the measured SS[17] from the Pauatahanui[18]. Assuming the sediment yield from the construction area remains as per the Assessed Analysis, the sediment attributed to the Project peak construction scenario increases from 2% to 4%, reflecting that the construction sediment yield is a slightly greater proportion of the baseline than assumed in the assessment (if this lower baseline is used).

44 The overall sediment entering the Harbour is reduced, so the "with construction" scenario using SSYE as a baseline in a Q10 event, yields less than the assessed yield in a Q10 event without the Project.

45 Harbour modelling was undertaken to assess the effect of a reduced baseline in the Pauatahanui. The scenario modelled was a 10 year ARI event in the Duck, Pauatahanui and Ration catchments, with 3.2 km of earthworks in the Ration and 1km of earthworks in the Duck catchment, and 2 year ARI events assumed in all other catchments. This staging was based on advice from **Mr Edwards**.

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16 As outlined in paragraph 103 of EIC, Dr Phillip Jordon is the global practice leader for modelling catchment processes at SKM. His CV is attached in **Appendix C**.

17 Suspended solids.

18 Hicks DM, Shankar U, McKerchar AI, Basher L, Jessen M, Lynn I, Page M 2011. Suspended sediment yields from New Zealand Rivers. Journal of Hydrology (NZ) 50: 81-142.

46 The increase in sediment from the Ration in this scenario is expected to be 578 tonnes, which is greater than the expected increase in sediment from the Pauatahanui when it is under construction. **Mr Roberts** has advised me that sediment discharged from Ration Stream is likely to be deposited in similar locations to the sediment discharged from the Pauatahanui Stream. Therefore, as I have outlined above, the modelling results from the Ration can be used to help understand the effects on the Harbour of a reduction of baseline sediment yield in the Pauatahanui catchment, in both the peak construction year in the Ration and the peak construction year in the Pauatahanui. **Mr Edwards** has advised that earthworks in the Pauatahanui and Ration catchments are not expected to occur at the same time.

47 The ecological effects of reducing the baseline estimate in the Pauatahanui in the 10 year ARI are discussed by **Dr De Luca**.

Uncertainty in the rating curve

48 In paragraph 7c of his evidence, Dr Basher suggests that it is difficult to know how accurate the process of transforming the average annual data to event loads is. In paragraphs 51 and 52, Dr Basher describes how he assumes the curves were developed. This description is incorrect. The rating curves were developed using the SSYE estimate of average annual sediment yield, 50 years of simulated daily peak flow data and the slope of the curve determined from the measured data. The A factor was determined by finding the same long-term average annual sediment yield as was predicted for the catchment using the scaled USLE. For the construction scenario the A factor in the rating curve was up scaled by the proportional increase in the USLE (with appropriate weighting by sub-catchment area).

49 Once the slope is set, the magnitude of the curve is calculated from the simulated flow data and estimate of average annual sediment yield. There is reasonable agreement between the measured data and the magnitude of the curve, which provides confidence in the average annual sediment yield estimate.

50 There is also agreement with the slope of the rating curves and measured daily sediment load data, which demonstrates that modelled loads do match observed load data, albeit for relatively short periods with recorded flow and sediment concentration data.

51 A slope of 1.9 is considered a conservative assumption that is consistent with the data. Choosing a slope of 1.9 is conservative because it distributes more sediment into the 2 year ARI flows and greater. These are the flows that are being assessed for ecological effects. The slope applies to both baseline and construction estimate, and therefore the slope factor does not alter the proportion between the baseline and construction scenario.

52 Uncertainty calculations have been undertaken to provide error limits around the slope and yield estimates (see **Appendix B**).

53 The long term Harbour simulation provides a calibration for the estimate of average annual sediment load. **Mr Roberts** has advised that the sediment accumulated in the Harbour after running the long term simulation was consistent with measured sediment deposition in the Harbour.

54 Uncertainty in the prediction of baseline event sediment yields is largely related to the natural variability in suspended sediment for a given return period flow.

55 The uncertainty in the baseline is likely to exceed the uncertainty associated with the construction scenario. The sensitivity analysis with no sediment control, has a sediment yield within the confidence limits of the baseline estimates in the 10 year ARI flow.

Q50 EVENT

56 In response to conferencing between Ms Kettles and **Dr De Luca**, further harbour modelling has been carried out. The modelled scenario is based on the following assumptions:

56.1 Annual earthworks stage assumptions:

Horokiri	3.0km	(22.5Ha)
Duck	1.9km	(14.25Ha)
Pauatahanui	0.1km	(0.75Ha)
Kenepuru	2.1km	(15.75Ha)
Porirua	0.2km	(1.5Ha)

56.2 50 year ARI rainfall in the Pauatahanui and Duck catchments, with a 2 year ARI rainfall elsewhere, and a 90th percentile Northerly wind.

57 A second modelled scenario assumed the same open earthworks areas, but with 50 year ARI rainfall in the Porirua and Kenepuru catchments, a 2 year ARI rainfall elsewhere, and a 90th percentile Southerly wind.

58 The ecological assessment of this modelling is discussed by **Dr De Luca.**

RESPONSE TO EVIDENCE OF SUBMITTERS

Witnesses responded to

59 My evidence responds primarily to the evidence of Dr Basher, but also comments on matters raised by Mr Handyside and Ms Kettles. My responses are grouped by topic, rather than by witness.

60 The essential issue as I understand it arising in relation to Dr Basher's evidence is whether the assessment I have reported on with reference to Technical Report 15 is sufficiently reliable in order for the Board to make findings on the nature and scale of sediment effects and their relationship to other effects.

61 With reference to Dr Basher's paragraph 68, I agree that it is not possible to precisely estimate the sediment yield for the Project (and that is the case for most projects). However, I consider that I have taken appropriate steps to derive reasonable estimates of sediment yield for the construction. The more detailed modelling in the Revised Estimate demonstrates appropriate consistency with the Assessed Analysis, and indeed shows that the Assessed Analysis produced conservatively high estimated sediment yields for most catchments.

62 In my view, the assessment, strengthened by the Revised Estimate, and the uncertainty analysis presents a sufficiently reliable prediction of sediment impact issues at this time.

Baseline Average Annual Sediment Yield

63 In paragraph 7 of his evidence, Dr Basher notes three limitations on the use of the USLE for the TGP.

64 The first of these limitations is that the USLE was only designed to predict soil loss from sheet and rill erosion, and that little of the current sediment yield is likely to be as a result of these processes. I agree with this point, and it was a primary reason for choosing a method that scaled the estimate of sediment generation using the USLE factors, to the SSYE[19]. The SSYE is a model that accounts for all erosion processes. In the conferencing statement (paragraph 10), Dr Basher and I agreed that the SSYE is the best method for providing the baseline sediment estimates.

65 The second limitation claimed in paragraph 7b of Dr Basher's evidence, is that the USLE is being used beyond the limits for which it is "calibrated". While he is correct, the method did not rely on the USLE to predict absolute yields for the baseline, but instead relied on the USLE's ability to categorise the relative importance of the catchments' characteristics in the generation of sediment, and then scaled these factors to the SSYE.

[19] Suspended sediment yield estimator.

66 With reference to Paragraph 8 of Dr Basher's evidence, I agree that the SDR, used to relate the sediment generation estimated using the USLE factors to the SSYE, is not just a sediment delivery ratio. It accounts for both sediment deposition in the catchment and over-estimation of sediment generation by the USLE, and therefore it is better described as a scaling ratio.

67 In paragraph 48, Dr Basher expresses concerns about the representation of the scaling of the USLE to the SSYE. I agree that the information presented in Table 15.18 of Technical Report 15 illustrates a check of the application of the scaling that was adopted, and not an independent validation of the method to the SSYE estimates.

Construction Sediment Yield

68 In paragraph 14 of the conferencing notes, Dr Basher and I agree that the USLE is the best method for estimating the effects of road construction on sediment yield from the road corridor.

69 With reference to paragraph 34 of Dr Basher's evidence, I agree the USLE is most commonly used for assessing the relative change in sediment associated with construction, and this is how it has been used for the TGP. The method used for the assessment of construction effects is a relative assessment, where the USLE factors are scaled to the SSYE to set the baseline, and the relative increase in sediment from the construction site is estimated by altering USLE factors.

70 For the assessment of effects described in TR15 and my EIC, the only USLE factor[20] that was altered was the 'C' factor for a given road length under construction, with an assumed width of 75m[21]. The effect of this was to increase the calculated baseline sediment generation rate per unit area in these locations by a factor of approximately 50 (compared to the "without Project" scenario). A sediment removal rate of 70% for the Q2 and Q10 and 40% for the Q50 was applied.

71 I accept using a higher sediment delivery ratio value for the construction scenario may be more representative of deposition

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[20] In paragraph 121 of my EIC, I describe the alteration of the SRE, P and C factors for the construction scenario. This was incorrect. The only USLE factor that was altered for the modelling, used for the assessment of effects, was the cover factor (c), and the assumption was made that 70% removal of sediment in the Q2 and Q10 and 40% in the Q50. However, all of these factors were altered for the Revised USLE Estimate, which is described in this rebuttal evidence.

[21] The road corridor is not 75m wide; on average the road corridor is 55m wide, the 75m wide assumption was to allow for other earthworks such as fill sites, lay down areas, enabling works and stream works, and to provide conservatism in the estimates.

processes.[22] The Revised Estimate undertaken after conferencing (and described above) used a SDR of 0.7 and 0.5 (which Dr Basher suggested). An SDR of 0.7 is usually used on slopes greater than 10%. In the Revised USLE Estimate I used an SDR of 0.7 for catchments with steeper longitudinal grade, although I note none of the longitudinal grades of the Project exceed 10%, and therefore I consider this to be a conservative assumption. As discussed in paragraph 14, all of the USLE factors were considered and revised as appropriate.

72 I disagree with Dr Basher's suggestion in paragraph 48d that scaling the USLE to the SSYE using the 0.17 factor may have seriously underestimated the likely increase in sediment related to the road construction. This is because, as stated above, the 0.17 is a scaling factor that does not just account for sediment deposition.

73 The Revised Estimate I have undertaken described in paragraphs 14 to 26, and in detail in the Revised Analysis report[23], has indicated that the assessed estimates using the scaled USLE method were consistent and generally conservative compared to the more detailed approach adopted for the Revised Analysis.

Brian Handyside's USLE example

74 In paragraphs 48 to 53 of his evidence, Mr Handyside carries out a sediment yield assessment of works in the Duck Creek Catchment. The sediment yield values quoted in paragraphs 50 and 53 of Mr Handyside's evidence are far in excess of what would be expected from this construction area.

75 The 'K'[24] factor used by Mr Handyside does not account for gravel or rock. The test pits and boreholes in this location indicate the colluvium soil ranging in depths between 1 – 5m is underlain by Greywacke rock. The Project in this location includes significant cuts and fills (in excess of 20m). The cuts are part of an area where 90% of the cut material is estimated to be in greywacke rock[25], and the fills are in crushed greywacke rock. The Revised Estimate of construction sediment yields (described in paragraphs 14 to 26 above) takes these ground conditions into account.

Comparison of construction yields to other sites

76 In paragraph 55 of his evidence, Dr Basher compares TGP sediment yield values with values from projects in Auckland. In my view, comparisons made to values in Auckland literature should be made

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[22] Conference notes paragraph 15.

[23] The Revised Analysis appended to the 20 January 2012 Conferencing Statement.

[24] Soil erodibility factor.

[25] See Table 3 in the Revised Analysis.

with cognizance that the Project's climate, terrain and geology are very different from the Auckland studies.

77 The rebuttal evidence of **Mr Brabhaharan** describes the geology and geotechnical conditions that have been used to inform the estimation of sediment generation. **Mr Brabhaharan** states[26]:

> "As the majority of the Project will be constructed in rock, this can be expected to generate far less sediments than the fine grained soils found in the Auckland area. Even the older alluvium between BHFFP and SH58 comprising silt, sandy silt and sandy silty gravel are coarser than the fine grained soils which are predominantly encountered in the Auckland area, and may be expected to generate less fine grained sediments."

78 I consider it is more appropriate to compare the estimate of sediment generation from the Project site to the current works at Muldoon's Corner on Rimutaka Hill Road because of the factors described above. The USLE estimate for the Muldoon's Corner works was 40,000 kg/ha (or 28000 kg/ha with an SDR of 0.7 applied). While this is an estimate, rather than a measured value, my understanding is that the erosion and sediment control measures in place at this site are managing the effects of erosion and sediment successfully. **Mr Brabhaharan's** rebuttal evidence contains photos of this Project.

Comparison with rating curves at other sites

79 Paragraph 55 of Dr Basher's evidence makes the point that changes in the cover across a large proportion of a catchment have been demonstrated to modify the slope of the relationship in the log-log domain between runoff from the catchment and sediment yield.

80 The examples provided by Dr Basher in paragraph 55, illustrate changes in curves where the construction footprint makes up more than 1% of the total catchment. In the Alexandra catchment in Auckland, 28% of the catchment was bare ground[27]. In the Motueka example[28], the harvested forest comprised up to 20% of the catchment.

81 Although Dr Basher makes a legitimate point that disturbance to a large proportion of a catchment will modify the sediment yield versus flow relationship, changes of 1% or less of each catchment area, as would be associated with construction of the Transmission Gully Project, are unlikely to result in an appreciable shift in the curve.

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[26] Paragraph 51.

[27] Auckland Regional Council, TP051 Storm Sediment Yields From Basins.

[28] Dr Basher, telephone discussion, 13 January 2012.

82 In this Project, the construction footprint makes up on average approximately 1% of the stream catchment areas[29]. At any one time, condition E.1 limits the maximum open earthworks area in the Porirua Harbour watershed to approximately 0.3% of the overall Porirua Harbour catchment (172km^2). In the Pauatahanui Inlet catchment (65km^2) the maximum earthworks area would be approximately 0.6% of the catchment, and in the Onepoto Arm (107km^2) the maximum earthworks area would be approximately 0.2%.

83 Therefore, while large increases in sediment yield are experienced at a construction site scale, at a catchment scale these increases are less significant.

Event loads

84 In Paragraph 50, Dr Basher refers to Table 25 in TR15, which illustrates the average loads discharged into the Harbour from each catchment in the 20 year long term simulation. I disagree with Dr Basher's interpretation of these results.

85 In the Ration, construction occurs during 1 year. In the simulation there were no significant rain events in that catchment in that year. Therefore the simulated average annual yield is lower than the average annual yield calculated using the USLE scaled to the SSYE.

86 However, in the Duck, the long term simulation included construction at a time when a series of larger rain events occurred. Therefore, the simulated average annual yield is higher than the average annual yield calculated using the USLE scaled to the SSYE for this catchment.

87 On average, the sediment generated from all the catchments and discharged to the Harbour was simulated as 3024 tonnes over the construction period. This compares to the calculated average annual treated sediment yield using the USLE scaled to SSYE of 3158 tonnes, which was the basis of the rating curves that were used for this simulation.

88 When I convert the simulated increase in tonnes to an untreated estimate of sediment yield this equates to 10,008 tonnes over the lifetime of the Project. The assumed area for this modelling was 170 ha over the life time of the project, draining to the Porirua Harbour. This equates to an average yield of 5929 T/Km^2 for the construction sites. The baseline estimate of yield for these catchments varies from 97 T/km^2 in the Porirua catchment, to 160 T/Km^2 in the Horokiri catchment. The construction average annual yield per unit area is approximately 50 times greater when compared to existing catchment average values. The increase in the

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[29] **Mr Edwards** EIC, appendix B

yield by a factor of 50 is related to modification of the USLE C factor, the C factor for bare earth is 50 times greater than the C factor for pasture.

89 The purpose of the long term simulation was to assess the effects on the Harbour in the long term, rather than to analyse the effects related to discharges from specific catchments in large events. It is my opinion that the long term simulation provides reliable estimates for this purpose.

Uncertainty associated with estimates

90 In reference to Dr Basher's paragraph 6, I agree that the lack of long term data is a constraint to assessing the uncertainty around the estimates of sediment yield modelled for the Project, and this is recognised in Technical Report 15[30]. This is an issue with nearly every construction site in New Zealand, as it is rare for appropriate long term data to exist. In my view, the question at this time is whether or not the estimates and associated assessment are sufficiently reliable indicators of the nature and scale of effects for the purposes of related effects assessment. I consider they are satisfactory, bearing in mind the role of conditions in managing effects.

91 I agree with Dr Basher's statement in paragraph 12 that more measured sediment data would increase the confidence in the estimated sediment yields, but disagree that this lack of data represents a "major constraint". I agree that further collection of sediment data in these catchments is warranted in future.

92 Similarly, it is difficult to accurately estimate uncertainty around sediment yield and event loads without long term measured data. There is long term data for the Pauatahanui and this, along with national data, was used to develop the SSYE. It is my opinion that the SSYE provides the most reliable estimate of baseline sediment yields for these catchments, and therefore has been used as the basis for estimating average annual sediment yield for this study.

Sediment deposition in streams

93 In paragraph 45, Helen Kettles considers whether sediment deposited in the Ration may reduce the overall baseline and result in an underestimation of the relative effects of the assessed construction scenario.

94 I consider that, while some sediment is likely to be deposited in the Ration stream, the assumption used in the modelling that all sediment yield from the catchment will be delivered to the Harbour is reasonable. The SSYE, which the sediment yield estimate is scaled to, does not account for sediment accumulation in streams.

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[30] Paragraph 10.1.

Hicks et al 2011, consider sediment entrapment to be a small effect because on a long term basis flood plain deposition will be offset to some degree by bank erosion and the data that the SSYE is based on is typically measured at gorge outlets to narrow coastal plains and thus already includes this influence[31].

95 With reference to Helen Kettle's evidence paragraph 68, I can confirm that sediment is measured entering the Harbour from the mouth of the Ration. The median TSS concentration measured from the Ration over 8 events was larger than the average TSS concentration from the Pauatahanui.[32] The highest concentration of 220g/m^3 on the Pauatahanui and 250 g/m^3 on the Ration was measured on 9 October 2009. The flow in the Pauatahanui was 6.8m^3/s at the gauging station at this time.

96 Harbour modelling has now been undertaken to assess the effects of a Q10 event in the Ration. This has included a scenario that considered a reduced baseline in the Pauatahanui. **Dr De Luca** discusses the ecological effects of this in her Rebuttal evidence.

Temporary stabilisation

97 In paragraph 53 of his evidence, Mr Handyside discusses the effect of temporary stabilisation and suggests that, if 50% of the 'unstabilised' area could be temporarily stabilised, this would have a significant reduction in sediment yield.

98 I agree with Mr Handyside on this point - temporary stabilisation is outlined as a key element of the erosion control philosophy for this Project[33]. Indeed, stabilisation is a continuum, so that earthworks areas in the process of being stabilised will generate progressively less sediment over time, even though they may not have reached "stabilised" status. In the Revised Estimate I have assumed that 25-50%% of the earthworks area is stabilised and not contributing sediment over background levels, and approximately 20% - 50% of the earthworks area is protected by erosion control measures achieving 75% reduction in sediment generation.

99 The erosion and sediment control plans and consent conditions will be important in ensuring that erosion and sediment control measures are applied.

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31 Hicks DM, Shankar U, McKerchar AI, Basher L, Jessen M, Lynn I, Page M 2011. Suspended sediment yields from New Zealand Rivers. Journal of Hydrology (NZ) 50: 81-142.

32 Technical Report 15, Appendix 15.E E1 and E2. Event Samples Medians.

33 Section 9 of Technical Report 15.

COMMENT ON CONDITIONS

100 **Dr Fisher** and **Mr Gough** both discuss and recommend additional consent conditions in their evidence. I recommend a change in approach to conditions E.1 and E.2 of the NZTA earthworks permits to specify length restriction in all the catchments that drain to the Porirua Harbour. My recommended lengths are based on the revised analysis, and also accommodate a degree of conservatism while still retaining some flexibility for detailed design.

101 The recommended annual road staging lengths for condition E.1 are as follows:

101.1 Ration catchment –a length not exceeding 3.2km at any one time;

101.2 Horokiri catchment –a length not exceeding 3.0km at any one time;

101.3 Pauatahanui catchment - a length not exceeding 1.8km at any one time;

101.4 Duck Creek catchment - a length not exceeding 1.9km at any one time;

101.5 Collins catchment - a length not exceeding 0.4km at any one time.

102 For condition E.2 I recommend a length not exceeding 2.1km in total at any one time.

103 In addition, I consider it important that the conditions require stabilising the open earthworks areas, on an ongoing basis. My understanding is that the areas described under condition E1 are not 'unstabilised areas', but rather describe annual staging areas, within which progressive stabilization will occur. I understand the erosion and sediment control plans will incorporate requirements for degrees of stabilisation to be achieved within these staging areas.

Michelle Kathleen Malcolm
27 January 2012

APPENDIX A – CONSTRUCTION SEDIMENT YIELD SENSITIVITY

1 The Revised USLE Estimate has provided a greater level of detail about the assumed areas that will be stablised and protected by erosion control measures during construction. It has been assumed that areas that are not stablised will be treated with sediment control devices. It is assumed that 80-95% of the area will be able to be treated wwth 3% sized sediment ponds achieving 70% performance in the 2 year and 10 year events, and the remaining areas being treated with a treatment train of devices achieving 30% performance in the Q2 and Q10. These performance and staging assumptions are based on advice from **Mr Gough** and **Mr Edwards**.

2 Conditions E3(j),E3(k) and E5(l) require that when heavy rain is forecast, all practical erosion control measures are applied. This was not accounted for in the Revised Estimate, so the Revised Estimate is conservative in this respect.

3 I have undertaken sensitivty analysis to consider the effect of improved or reduced erosion and sediment control, and have considered two scenarios:

3.1 Scenario One: stabilization as with Revised Analysis with more stablization in Kenepuru and Ration, erosion control applied to active areas that is 50% effective, reduced sediment control.

3.2 Scenario Two – Staging control as per the Revised Estimate, erosion control that is 50% effective , no sediment control.

4 The staging and performance assumptions for the scenarios are described in the tables below.

Table 2: Scenario One Assumptions: increased stabilization, erosion control, erosion control in all areas during heavy rain, reduced sediment control.

Scenario One :Erosion and Sediment Control for the Road Cross Section					
	Erosion Control			Sediment Control	
Control Measure	Stabilized	Erosion Control	Active earthworks	Chemical treatment Ponds 3%	Ponds earth decanting bunds, <3% chemical ponds, silt fences etc
Performance	100%	75%	50% in heavy rain	50% Q2 and Q10 and 25% in Q50	10% in the Q2 and Q10 and 5% in the Q50.
Kenepuru	50%	31%	19%	95%	5%
Duck	25%	23%	52%	95%	5%
Pauatahanui	25%	23%	52%	95%	5%
Ration	40%	23%	37%	95%	5%
Horokiri	25%	23%	52%	80%	20%
Te Puka	25%	23%	52%	80%	20%
Stream works					100%
Fill sites				100%	

Table 3: Scenario One Results: stabilization as with revised analysis with more stablization in Kenepuru and Ration, erosion control applied to active areas that is 50% effective, reduced sediment control.

	Increase in sediment yield due to construction				
	Revised Estimate, actual area (T)		Scenario one construction yield increase, actual area (T)		% change
	Q2	Q10	Q2	Q10	
Kenepuru	60	168	58	163	-3%
Duck	28	131	25	118	-10%
Pauatahanui	17	106	15	94	-11%
Ration	105	522	94	471	-10%
Horokiri	39	212	33	179	-15%
Te Puka	371	1885	316	1605	-15%

5 These results show that stabilisation before heavy rain events achieves a reduction in sediment yield compared with that calculated in the Revised USLE Analysis. In all catchments, with the exception of Kenepuru, the assessed yields discussed in TR15 are conservative compared with this scenario. In the case of the Kenepuru, the yield is conservative compared with the most recent harbour modelling which modelled an increase in sediment as a result of constrction which was 168 tonnes. **Dr De Luca** discusses the effect of the increased construction sediment in the Onepoto Arm of the harbour.

6 This analysis demonstrates the importance of erosion and sediment control measures working in conjunction with each other. In this case the lower assumed performance of the sediment ponds is offset by accounting for the deployment of erosion control measures when heavy rain is forecast. The stabilized areas in the Kenepuru and Ration were also increased in this scenario. This is considered to be a realistic assessment of the proportion of the area that would be stabilised and under erosion control in these catchments.

Table 4: Scenario Two – Staging control as per the revised estimate, erosion control is less effective, not sediment control.

Erosion and Sediment Control for the Road Cross section					
Control Measure	Erosion Control			Sediment Control	
	Stabilized	Erosion Control	Active earthworks	Chemical Treatment Ponds 3%	Ponds earth decanting bunds, <3% chemical ponds, silt fences etc
Performance	**100%**	**50%**	**0%**	**0%**	**0%**
Kenepuru	25%	56%	19%	95%	5%
Duck	25%	23%	52%	95%	5%
Pauatahanui	25%	23%	52%	95%	5%
Ration	25%	37%	38%	95%	5%
Horokiri	25%	23%	52%	80%	20%
Te Puka	25%	23%	52%	80%	20%
Stream works					100%
Fill sites				100%	

■ **Table 5: Results Scenario Two – Staging control as per the revised estimate, erosion control is less effective, no sediment control**

	Scenario Two: Increase in sediment yield due to construction				
	Revised Estimate		Scenario Two construction yield increase, actual area (T)		
	Q2	Q10	Q2	Q10	% change
Kenepuru	60	168	254	711	323%
Duck	28	131	97	446	240%
Pauatahanui	17	106	57	361	241%
Ration	105	522	385	1921	268%
Horokiri	39	212	112	612	189%
Te Puka	371	1885	1053	5351	184%

7 The results show signficant increases in sediment yield at the construction site. To assess the potential effect of these increases they should be considered in the context of the baseline from the larger catchment. Table 6 provides a summary of the sediment yields that have been assessed, and the change in sediment at the mouth as a result of construction.

■ **Table 6: Assessed increase in sediment at 6 stream mouths.**

	Assessed Baseline (without road) (T)		Assessed construction (T)		% change between baseline and construction at the mouth
	Q2	Q10	Q2	Q10	
Kenepuru	375	1051	415	1162	11%
Duck	343	1582	402	1854	17%
Pauatahanui	695	4426	711	4526	2%
Ration	271	1353	387	1931	43%
Horokiri	689	3754	789	4300	15%
Te Puka	1710	8688	2212	11238	29%

Table 7: Increase at the stream mouths for scenario two, with reduced erosion control and no sediment control.

	Assessed Baseline (without road) (T)		Sensitivity actual area Peak/Harbour (T)		% at the mouth
	Q2	Q10	Q2	Q10	
Kenepuru	375	1,051	629	1,761	68%
Duck	343	1,582	439	2,028	28%
Pauatahanui	695	4,426	752	4,786	8%
Ration	271	1,353	657	3,274	142%
Horokiri	689	3,754	801	4,366	16%
Te Puka	1710	8688	2,763	14,039	62%

8 Scenario Two is not considered a likely scenario because erosion and sediment control measures are an integral part of the Project's construction. However, it illustrates the importance of erosion and sediment control measures in achieving the assessed sediment yields entering the receiving environments.

9 Scenario One illustrates that the erosion and sediment control philosophy in TR15 and reflected in the conditions, provides a suite of erosion and sediment control measures, which when considered working together, significantly reduce the potential sediment yield.

10 The sensitivity analysis has confirmed my conclusion in my EIC that, assuming the consent conditions are confirmed as proposed, and that the proposed management plan framework is accepted and implemented, it is my opinion that the potential adverse water quality effects can be managed to an acceptable level. The potential ecologcial effects of the construction discharges are discussed by **Dr Keesing** and **Dr De Luca**.

Unaccounted for sources of sediment

11 Mr Handyside identifed in conferencing on 20 January 2012[34] that he considered that not all the potential sources sediment had been accounted for. He identified enabling works and stream works as two potential sources of additional sediment. Dr Hicks also identified stream works as a potential source of sediment.

Enabling works

12 I have undertaken analysis to identify the sediment yield that could be expected from the enabling phase of the Project, that is

[34] 20 January 2012 Conferencing Statement.

prior to the main earthworks. The performance and staging assumptions are based on advice from **Mr Gough** and **Mr Edwards**.

Table 8: Enabling works area assumptions

Enabling Works	Total Area (Ha)	Description	Enabling works area assumed within 6 catchments. (Ha)					
			Te Puka	Horokiri	Duck	Ration	Kenepuru	Pauatahanui
Transpower Towers (enabling)	1	Based on 24 new towers	0.50	0.50				
Temporary culverts (enabling)	1	55 No	0.17	0.17	0.17	0.17	0.17	0.17
Haul roads	2.5	based on 5km of new tracks 5m wide	0.42	0.42	0.42	0.42	0.42	0.42

Table 9: Enabling works sediment yield (untreated)

Catchment	Sediment Yield kg/ha/yr	
	Enabling works + haul road	Stream works
Duck	98322	4371
Horokiri	126186	2951
Kenepuru	52749	11225
Te Puka	93196	7169
Ration	41335	7523
Pauatahanui	37738	2229

13 For this scenario it has been assumed there is no treatment. This is a very conservative assumption because it is most unlikely to ever occur. The enabling works will be managed with sediment control devices.

Table 10: Enabling works results

	Assessed construction yield (T)		Sensitivity construction yield (T) Enabling works, Stream works, haul road		% change
	Q2	**Q10**	**Q2**	**Q10**	
Kenepuru	60	168	14	39	-77%
Duck	28	131	15	67	-49%
Pauatahanui	17	106	2	12	-88%
Ration	105	522	7	36	-93%
Horokiri	39	212	15	80	-62%
Te Puka	371	1885	87	442	-77%

14 The results illustrate that, even with the conservative assumptions of:

14.1 No erosion and sediment control; and

14.2 All the planned enabling works occuring within one year and only within the catchments being assessed,

the assessed scenarios are far in excess of the sediment that has estimated to be generated during the enabling works phase. Accordingly, the assessment of effects based on the construction of the main earthworks can be used to assess the effects of the enabling works phase of works.

Stream works

15 The estimation of sediment yield from areas described as stream works using the Revised USLE, is limited in scope to those areas outside of the wetted channel and accounts only for erosion of these areas by rain. Stream works were separated from the earthworks in the road cross section for three reasons:

15.1 The soil found in and near to the stream channel has a high gravel content;

15.2 The grade of the stream works is related to the natural stream grade, rather than the road cross section; and

15.3 The erosion and sediment control measures used for stream works may differ from those used for the road construction due to limited space in some locations. The assumptions for erosion and sediment control for stream works are described in Table 12 of the USLE Revised Analysis report.

Table 11: Soil descriptions from test pits close to stream works locations

Stream	TP	Clay	Sand	Silt	Gravel
Duck	85,44,90,89	0%	14%	45%	41%
Horokiri	52,168,54,57,62	9%	19%	9%	63%
Kenepuru	48	0%	30%	7%	63%
Te Puka	21	0%	0%	35%	65%
Ration	126,128	0%	5%	43%	52%
Pauatahanui	1,151,148	4%	23%	31%	42%

16 **Mr Gough** has advised he considers the sediment generated by stream works due to scour and working in the wetted channel to be manageable because:

16.1 In general terms, culvert construction and stream realignment will be undertaken "in the dry". Where works are required to be undertaken in channels, a bypass will be provided to divert stream flows.

16.2 The Enabling Works include culverting which will be undertaken prior to commencement of the period of the Transmission Gully Highway construction earthworks.

16.3 The Linden SSEMP has considered the details of the staged construction of a culvert over a major gully fill, giving details of sediment control management during the period of culvert construction. This is a relatively complex procedure and a detailed methodology has been provided to show how the culvert is constructed in dry conditions. In the event of a high rainfall event being predicted during the construction period, the Contractor would promptly excavate and stabilise a channel to divert runoff flows across the top of the fill to the stream, with geotextile, biosock and riprap used to construct temporary erosion protection at the downstream discharge point to the existing watercourse.;

16.4 The Kenepuru, SH58 and Te Puka SSEMPs all describe staging details for the construction of major stream realignments. With the exception of parts of the Te Puka works, realignments are carried out in the dry, negating the need for bypass construction. Where works are undertaken in streams, provision is made for diverting stream flows.

16.5 **Craig Martell** has advised:

(a) In the Horokiri and Te Puka the new waterways are being built above current flood levels, i.e. the earthworks are not expected to be inundated in 10 year storm.

(b) Velocities in the lower section of the Pauatahanui are relatively low but a large storm could inundate works, and this would need to be considered in the detailed outline plans for this location. It should be noted that the construction timeframe for this should be relatively short (4-5 months) and it is likely to be undertaken well ahead of other major earthworks in this location.

APPENDIX B – UNCERTAINTY ANALYSIS OF THE BASELINE AVERAGE ANNUAL AND EVENT YIELDS

1 Dr Phillip Jordon of SKM, with my assistance, has undertaken the uncertainty analysis of baseline average annual and event yields.

Uncertainty in the estimation of the average annual sediment yield

2 The calculation of the baseline average annual sediment yield was calculated by describing the the catchments using the USLE factors and scaling these to the SSYE.

3 The overall uncertainty in the suspended sediment yield estimates from each of the catchments is comprised of two components:

3.1 The uncertainty introduced by scaling the estimated yields from the USLE to the yield estimates from the NIWA suspended sediment yield; and

3.2 The inherent uncertainty in the NIWA suspended sediment yield estimates.

4 The uncertainty in the first component was estimated using the figures presented in Table 15.18 of Technical Report 15. For each of the eight catchments, the mean annual sediment yield from the SKM USLE approach was divided by the NIWA suspended sediment yield estimate (Hicks et al., 2011); the natural logarithm was taken of each of these ratios and the sample standard deviation computed of those logarithms. The resulting standard log residual calculated from the first component (comparing SKM USLE with NIWA SSYE) was 0.26. Hicks et al. (2011) quotes the standard log residual in the NIWA SSYE estimates for North Island catchments as 0.59. If the errors in the ratio of each component are assumed to be log-normally distributed, then by taking the square root of the sum of squares of the log residuals the overall standard error of the log residuals was 0.65. This translates to 95% confidence limits for the overall uncertainty in the sediment loads as between 0.31 and 3.2 times the best estimate values that were presented in Technical Report 15. Estimated loads from the catchments under existing conditions (with no road) estimated using the approach presented in Technical Report 15 could therefore be between 0.31 and 3.2 times the values presented in the report. By comparison the SSYE average annual estimates coudl be between 0.35 and 2.9 times the average annual estimate.

Uncertainty in the rating curve

5 The rating curve that distributes the average annual yield across events was developed using the average annual yield calculated from scaling the USLE to the SSYE and 50 years of simulated daily

peak flow data for rain days. The slope of the line defines the proportion of the sediment that is delivered in the larger flows.

6 The slope of the line was determined by examining the slope of the measured sediment yield data. A slope of 1.9 was determined for all sites.

7 A regression fit has been developed for the Horokiri, Porirua and Pauatahanui catchments. The raw sediment yield and flow data was used to fit (in log-log domain) sediment load v flow rating curves for each of the three catchments.

8 This produces confidence limits around the slope of the regression line.

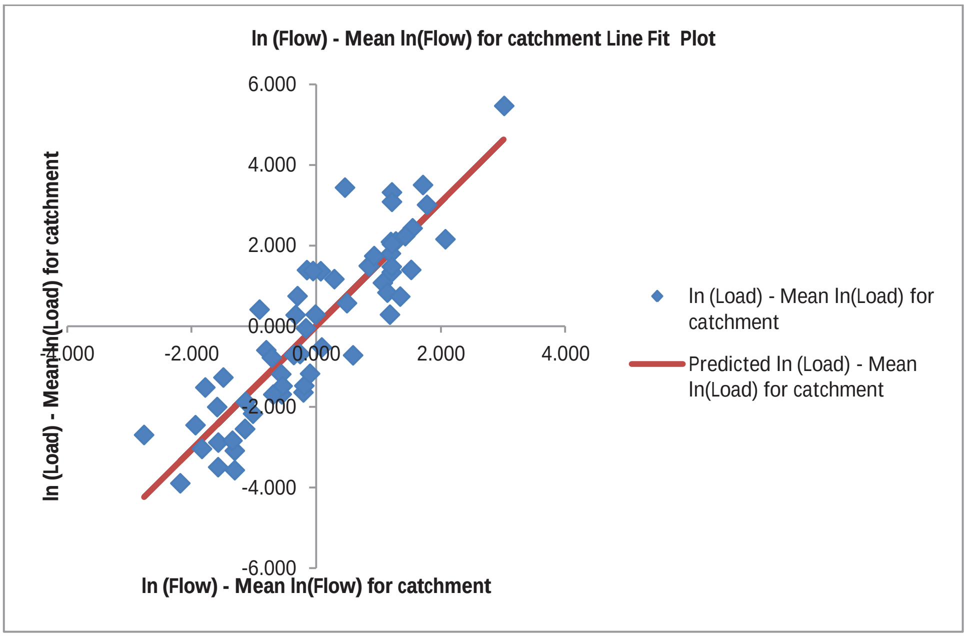
Catchment	**Expected Value**	**95th lower**	**95th upper**
Pauatahanui	1.04	0.44	1.64
Porirua	1.84	1.19	2.48
Horokiri	1.63	1.36	1.89

9 A slope of 1.9 was chosen for all catchments, this represents the 95th percentile for the Horokiri and is close to the expected value for the Porirua.

10 A combined regression fit for the Pauatahanui, Porirua and Horokiri streams was fitted. This was done by subtracting the mean of the logs for each catchment for both flow and load, and then fitting a relationship to that. Four outliers (with standard residuals > 2 sd away from the mean response) were then removed and the relationship was then re-fitted to the combined data.

11 The best fit slope of the regression relationship (B value) for the combined data was 1.53. The 95% confidence limits on the B value are 1.34 to 1.73.

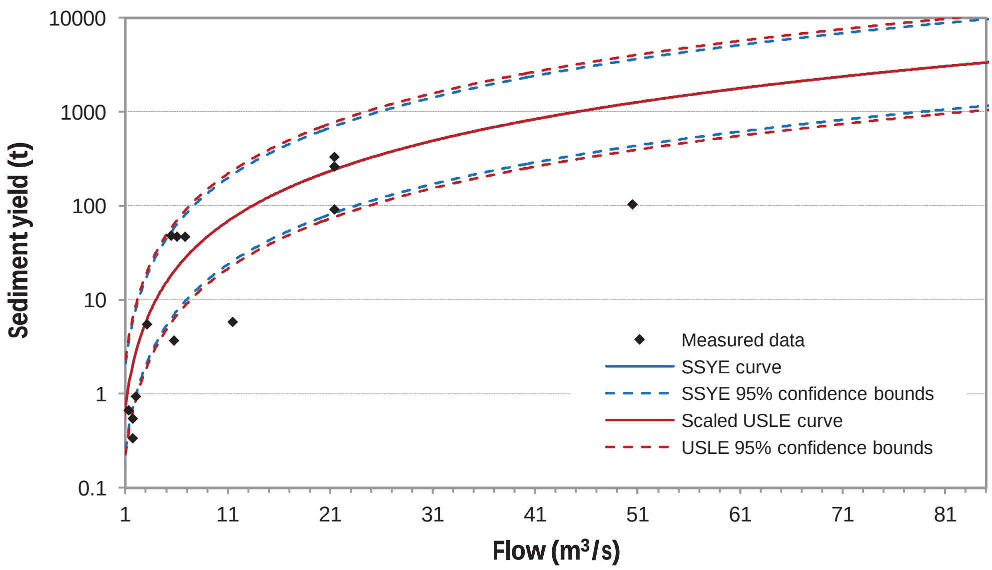
- **Figure 1: In(flow)-Mean in (flow) for Catchment Line Fit Plot**



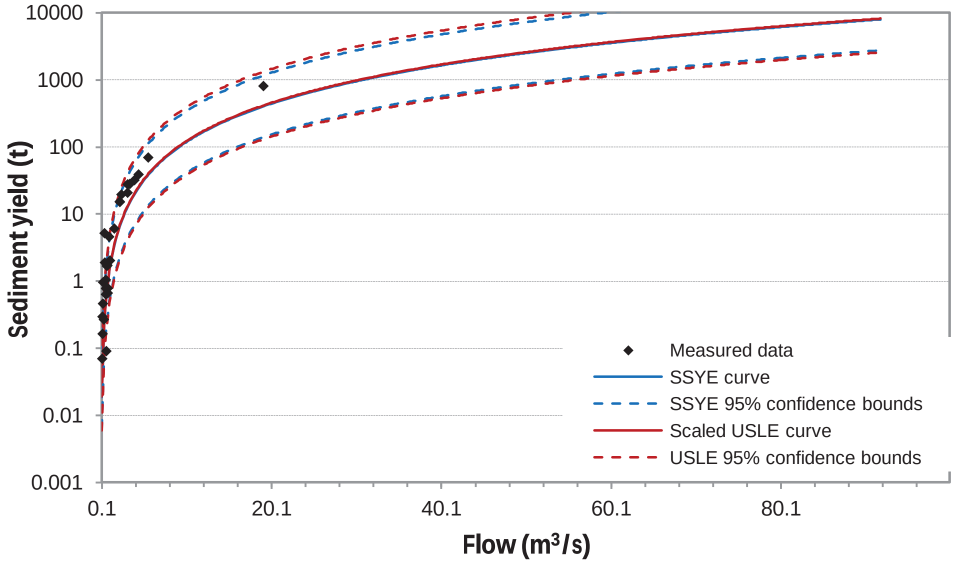
Sensitivity analysis in the rating curve

12 I have plotted two rating curve slopes, accounting for the confidence limits around the SSYE and the Scaled USLE.

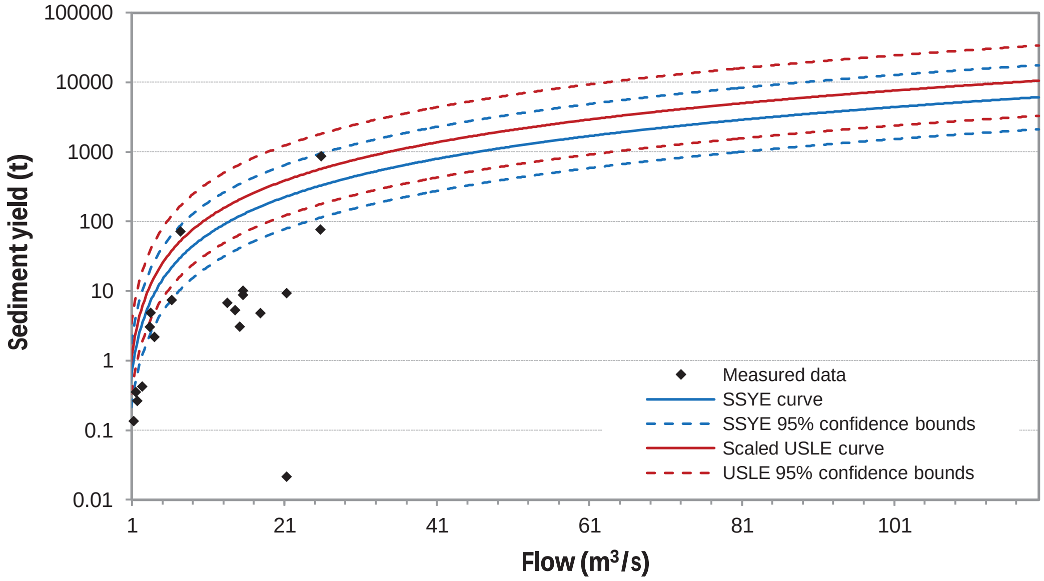
- **Figure 2: Porirua Rating Curve 1.9 exponent**



■ **Figure 3: Horokiri Rating curve exponent 1.9**



■ **Figure 4: Pauatahanui Rating curve 1.9 exponent**

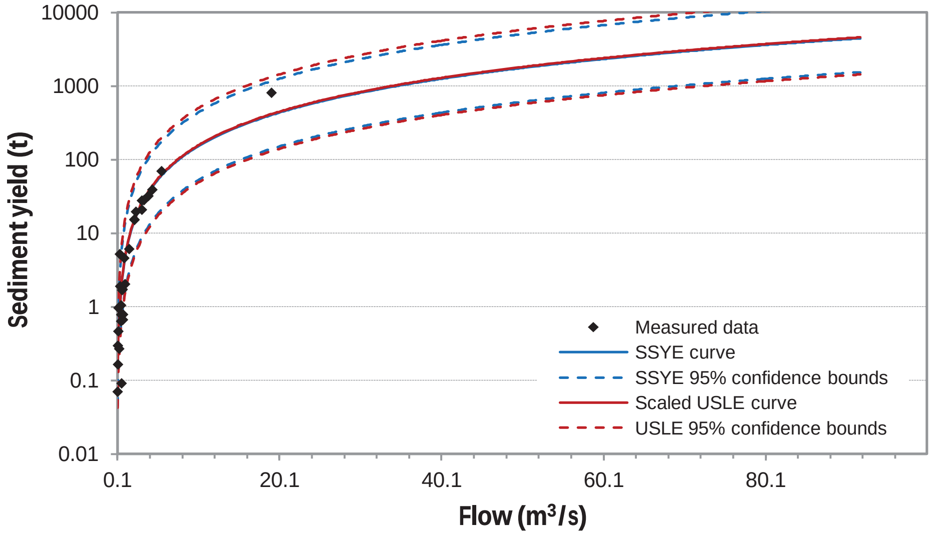


13 In the Pauatahanui the scaled USLE was higher than the SSYE. In paragraph 45 of Ms Kettles evidence she questions whether, if the baseline was over estimated in relation to the construction scenario, the ecological effect may be under estimated. I consider that the Pauatahanui baseline may have been over estimated. The Pauatahanui catchment was the only catchment where there is significant difference between the SSYE and scaled USLE. I consider the estimation of the baseline for all other catchments to be based on the best estimate, recognising there is wide natural variability in baseline suspended sediment in events. Additional harbour

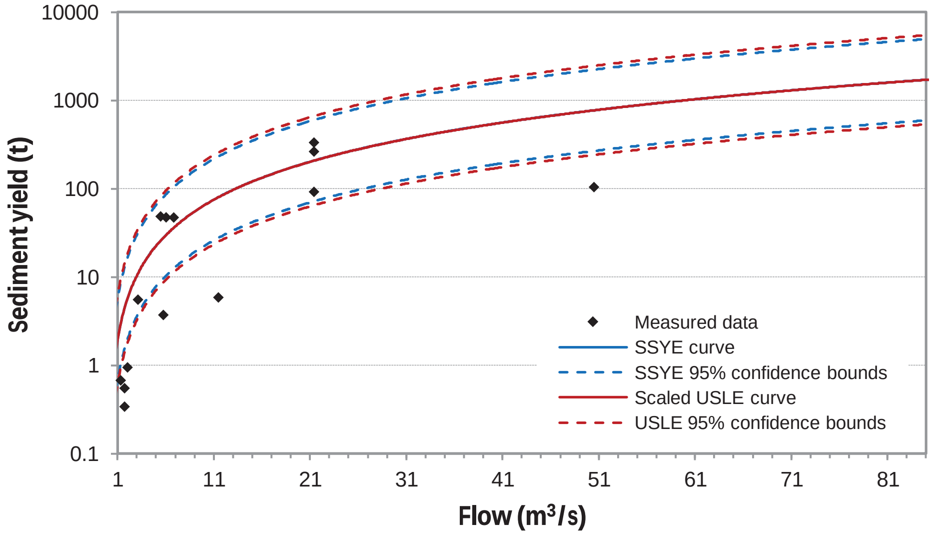
modelling has been undertaken to assess the effect of a reduced baseline that is based onthe SSYE estimate of average annual sediment yieldin the Pauatahanui catchment. The ecological effects of this modelling are discussed by **Dr De Luca.**

14 Sensitivity analysis has been undertaken to consider the difference in event yield that would result from choosing a lower slope of 1.53.

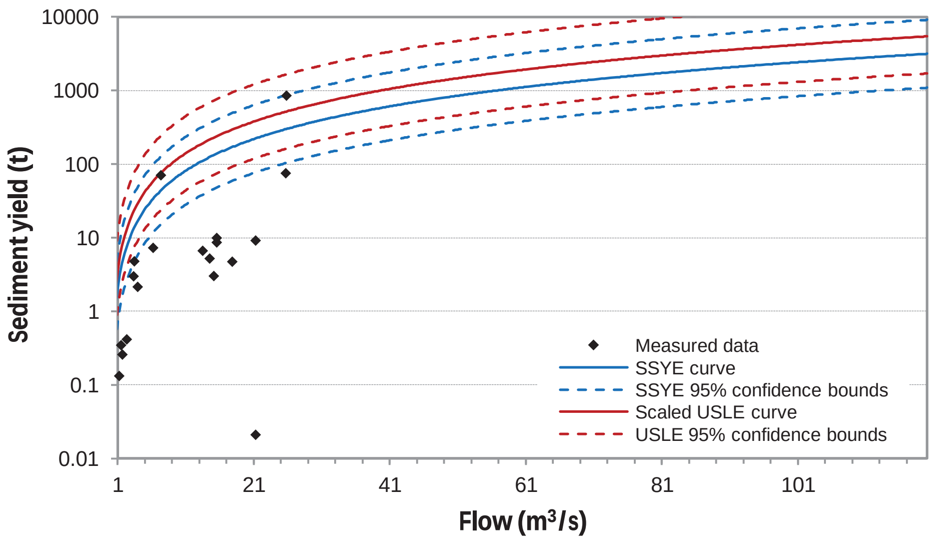
- **Figure 5: Horokiri rating curve exponent 1.53**



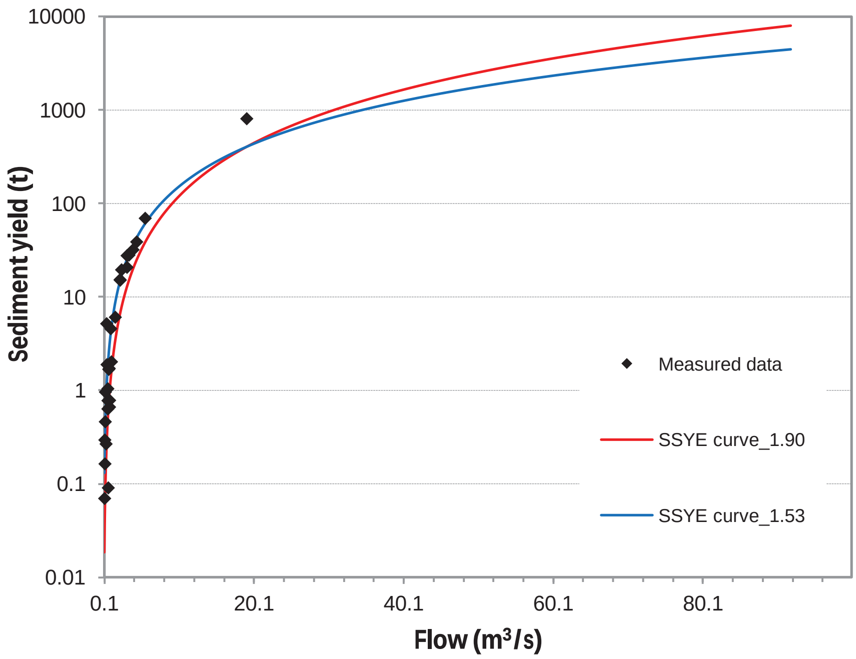
- **Figure 6: Porirua Rating curve exponent 1.53**



- **Figure 7: Pauatahanui Rating curve exponent 1.53**

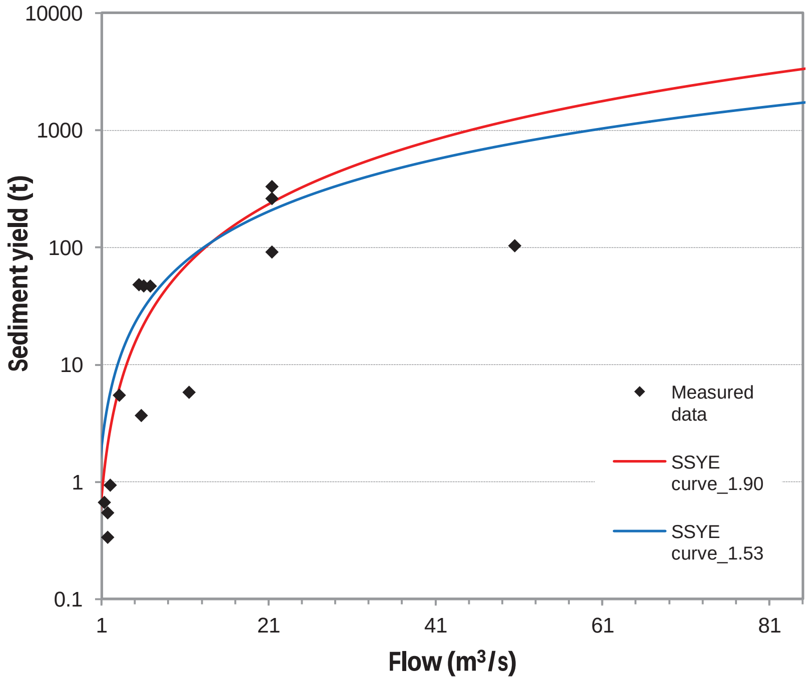


- **Figure 8: Horokiri Intersection of 1.9 and 1.53 curves**



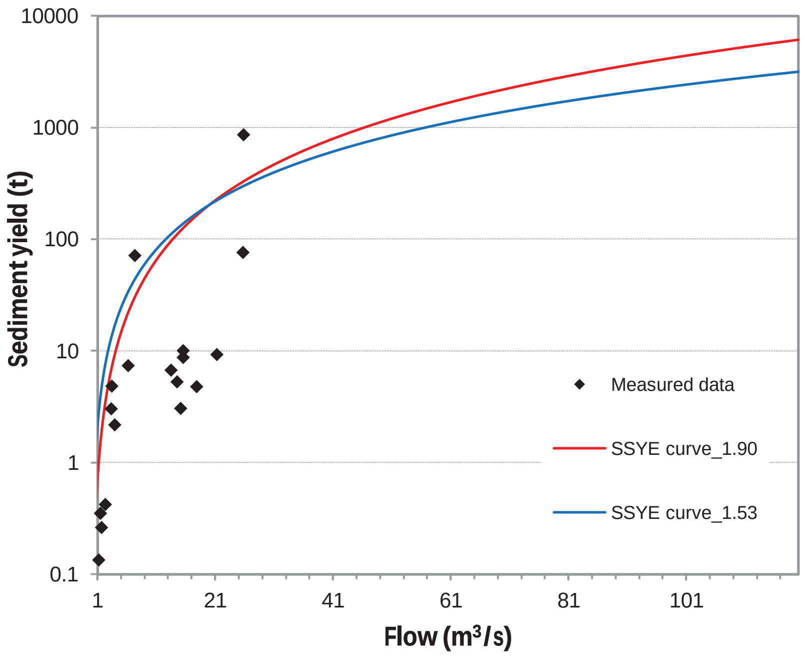
15 The insection of these slopes is at 19.2m^3/s. This is less than the 2 year ARI event.

■ **Figure 9: Porirua Intersection of 1.9 and 1.53 curves**



16 The insection of these slopes is at 17.2m^3/s. This is less than the 2 year ARI event.

■ **Figure 10: Intersection of 1.9 and 1.53 slopes Pauatahanui**



17 The insection of these slopes is at 19.8m3/s. This is less than the 2 year ARI event.

18 I think it is appropriate to choose the slope of 1.9, even though it is higher than the combined slope for all catchments. This is because the data that was collected was over a short term and the yields were calculated on a daily basis. Therefore, I consider the data is more useful to confirm the magnitude of the sediment yield which is calculated from the USLE scaled to the SSYE and to inform the choice of the rating curve slope.

19 1.9 is considered a conservative assumption that is consistent with the data. Choosing a slope of 1.9 is conservative because it distributes more sediment into the 2 year ARI flows and greater. These are the flows that are being assessed for ecological effects. The slope applies to both baseline and construction estimate, and therefore the slope factor does not alter the proportion between the baseline and construction scenario

20 The long term harbour simulation provide a calibration for the estimate of average annual sediment load. **Mr Roberts** advised that the sediment accumulated in the harbour after running the long term simulation was consistent with measured sediment deposition in the harbour.

Uncertainty in the construction estimates

21 The uncertainty in the baseline is likely to exceed the uncertainty associated with the construction scenario. The sensitivity analysis with no sediment control, has a sediment yield within the confidence limits of the baseline estimates.

22 I consider the best way of managing uncertainty associated with the construction yields is through the consent conditions; these include monitoring conditions that will improve the understanding of sediment yield from these catchments over time.

APPENDIX C: DR PHILLIP JORDON

Phillip Jordan

Role Senior Hydrologist

Sinclair Knight Merz *2003 - present*

Qualifications B.Eng. (Hons) University of Queensland

Ph.D. Monash University

Affiliations Chartered Professional Engineer

Member of Engineers Australia

Fields of special competence

- Development and calibration of rainfall-runoff models.
- Incorporating impacts of climate change in hydrological modelling.
- Stochastic generation of climate data for application in hydrological modelling.
- Statistical analysis of time series of rainfall and stream flow.
- Development of specialist computer code for hydrological modelling.
- Analysis of radar rainfall data and application to modelling of streamflow.

Summary of competency

Dr Phillip Jordan has fourteen years of experience in hydrology and water resources engineering. He has well-developed skills in statistical hydrology and modelling. He holds a B.E.(Hons.) from the University of Queensland and a Ph.D. from Monash University. Phillip has applied and developed a number of water resource models for uses such as:

- Evaluating capacity constraints in water resources systems using the MSM-Bigmod model, including the Barmah Choke;
- Simulating daily flow and salinity of river and irrigation systems using MSM-Bigmod including the downstream impacts of changed salinity.
- Assessing water availability for different climate and development scenarios as part of Murray Darling Basin Sustainable Yields Project.
- Development of sustainable diversion limits for 1900 catchments in South-West Western Australia.

Phillip is the product project leader for the eWater CRC's Catchment and Climates Project, which is developing the Water and Constituent Accounting and Simulation Tool (Watercast). He has applied the Watercast model to catchment management planning studies in Hornsby Shire (near Sydney), the Nerang River (Gold Coast City council) and for the Googong River (ACT water supply system). Phillip was the project manager and technical leader of the development of Sustainable Diversion Limits for unregulated catchments in the South West of Western Australia. He has produced forecasts of climatic data for the review of Canberra's water supply system. Phillip has applied and customised water resources models of Australia's Murray River in studies that developed strategies for the future management of the River, including consideration of climate variability.

Phillip has authored or co-authored six papers that have appeared in Australian and international journals and twenty-one conference papers. His research and consulting interests include hydrological modelling, stochastic hydrology and applications of meteorological radar in hydrology.

Relevant projects include:

- Product Project Leader for the Water and Contaminant Simulation and Accounting Tool (WaterCAST) in the eWater Cooperative Research Centre;
- Modelling projected effects of future farm dam impacts on runoff from every subcatchment in the Murray Darling Basin, as part of the 2007 Sustainable Yield study.
- Modifications to the FORTRAN code for the MSM and Bigmod models, to assess the impact of water trading on supply constraints for the Murray River: Project management and technical roles;
- Project manager for estimation of sustainable diversion limits for water from unregulated catchments in South West Western Australia. This project involved analysis of hydrological data from 160 catchments, use of an expert panel process to set the sustainable diversion limits in the gauged catchments and regionalisation of the results for application to 1900 ungauged catchments.
- Stochastic generation of climate data series for the Canberra Water Resources Strategy. Stochastic data was applied to rainfall-runoff and demand models to quantify water availability and security of supply for Canberra. Potential effects of climate change were incorporated into the model.
- Project Director for application of the SEBAL technique for remote sensing of evapotranspiration to estimate water balances for four case study regions in south eastern Australia.
- Development of WaterCAST catchment model of Hornsby Shire, including customisation of the model framework using the TIME modelling environment, Task management and technical roles;
- Project manager for update of the REALM model for the Tarago/Bunyip supply system, Victoria. Derivation of unimpacted and current daily flow time series for monitoring locations in the Tarago/Bunyip catchment system, Victoria.
- Project manager for update of REALM water resources model for the Werribee River, Victoria.
- Writing of FORTRAN computer code for the CHEAT model, which is used to perform water balance computations for individual farm dams within a catchment based on GIS information.
- Hydrological and hydraulic modelling for upgrades to flood capacity at Cairn Curran Dam. This included the use of radar data to improve the calibration of the RORB rainfall runoff routing model for deriving design floods.
- Derivation of rainfall depths for use in assessment of landslide risks across Tasmania.
- Updating and customisation of FORTRAN code for the monthly REALM water resources simulation model of the Murray River.
- Development of a water management plan for three ephemeral lakes in the Avon River Plains.
- Statistical trend analysis to estimate measurement accuracy for Dethridge wheel flow meters in the Katandra Invergordon irrigation district, northern Victoria.
- Hydraulic modelling and consequence assessment for several dams across Victoria.

Selected Papers and Presentations:

Jordan, P.W., Seed, A.W. and Weinmann, P.E., A Stochastic Model of Radar Measurement Errors in Rainfall Accumulations at Catchment Scale, *Journal of Hydrometeorology*, **4**(5), pp. 841–855, 2003.

Nathan, R.J., Jordan, P. and Morden, R. Assessing the impact of farm dams on streamflows, Part I: Development of simulation tools, *Australian J. Water Resources*, **9**(1), pp. 1-12, 2005.

Jordan, P., Nathan, R., Mittiga, L., Pearse, M. and Taylor, B. Growth curves and temporal patterns for application to short duration extreme events, *Australian J. Water Resources*, **9**(1), 69-80, 2005.

Jordan, P.W. and Hill, P.I., Use of radar rainfall data to improve calibration of rainfall-runoff routing model parameters, *Aust. J. Water Resources*, **10**(2), 139-149, 2006.

Pearse, M.A., Jordan, P.W. and Collins, Y.L, A simple method for estimating RORB model parameters for ungauged rural catchments, *27th I.E. Aust. Hydrology and Water Resources Symp.*, Institution of Engineers Australia, Melbourne, May 2002.

Jordan, P., Murphy, R., Hill, P. and Nathan, R., Seasonal response of catchment runoff to forest age, Proc. *30th Engineers Australia Hydrology and Water Resources Symp.*, Launceston, December 2006.

Kiem, A., Clifton, C. and Jordan, P., Assessing the vulnerability of Victoria's water resources due to climate variability and change, *Proc. Water Down Under 2008*, Adelaide, 15-17 April 2008, 759 – 772.

Jordan, P., Wiesenfeld, C., Hill, P., Morden, R. and Chiew, F., An assessment of the future impact of farm dams on runoff in the Murray Darling Basin, Australia, *Proc. Water Down Under 2008*, Adelaide, 15-17 April 2008, 1618 – 1629.

Lang, S., Jordan, P., Durrant, J. and Nathan, R., Defining sustainable diversion limits in unregulated south-west Western Australian catchments, *Proc. Water Down Under 2008*, Adelaide, 15-17 April 2008, 145-156.