Tauranga Harbour Sediment Study: Assessment of predictions for management

NIWA Client Report: HAM2009-139
Amended May 2010
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Tauranga Harbour Sediment Study: Assessment of predictions for management

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Prepared for

Environment Bay of Plenty

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Executive Summary

In order to better understand sediment sources and fate of sediment entering Tauranga Harbour, Environment Bay of Plenty contracted NIWA to conduct the Tauranga Harbour Sediment Study. The outcome of the study will be to appropriately manage growth and development now and in the future. This knowledge will assist in adapting and prioritising management rules and practices for the catchment and harbour with a full understanding of likely sedimentation effects for changes expected in landuse and the anticipated effects of climate change to 2051.

The study began in April 2007 and was scheduled to run for 3 years. The study area was defined as the southern harbour, extending from Matahui Point to Rangataua Bay in the south. The main aim of the study was to develop a model or models to be used to: (1) assess the relative contributions of the various sediment sources in the catchment surrounding Tauranga Harbour, (2) assess the characteristics of significant sediment sources, and (3) investigate the fate (dispersal and deposition) of catchment sediments in Tauranga Harbour. The study also addressed questions such as: (1) Which catchments are more important as priority areas for focusing resources to reduce sedimentation in the harbour? (2) What are the likely effects of existing and future urban development on the harbour? (3) How can the appropriate regulatory agencies (EBoP, WBPDC and TCC) most effectively address sedimentation issues, and what management intervention could be appropriate? (4) Are there any reversal methods, such as mangrove control and channel dredging, that may be effective in managing sedimentation?

The study brief called for using primarily existing datasets to build and drive a series of numerical models. (1) The GLEAMS catchment model was used to predict daily sediment runoff from each subcatchment. It was also used to compare sources of sediment under various scenarios including present-day landuse, likely future development and climate change. GLEAMS was also used to assess sediment characteristics of significant sources. (2) The DHI FM (Flexible Mesh) hydrodynamic and sediment models and the SWAN wave model were used to develop predictions of sediment dispersal and deposition at the "snapshot" or event scale, including during and between rainstorms and under a range of wind conditions. (3) The USC-3 sedimentation model was used to make predictions of sedimentation, bed-sediment composition and linkages between sources and sinks, following division of the catchment into subcatchments and the estuary into subestuaries. The model provides predictions at decadal time scales.

The models were validated using measured stream exports, harbour bed sediment mapping, and measurements of tides, waves and sedimentation rates in the harbour. Together, the models predict sediment runoff from 17 subcatchments and dispersal and deposition of sediment in 26 subestuaries of the harbour. Predictions were made by the models for three scenarios: 1) existing landuse under present-day weather, 2) present-day weather and landuse change as defined by SmartGrowth, and 3)

landuse change and the anticipated effects of climate change to 2051. The timeframe for the model predictions is 50 years from the present day (2001).

The model predictions quantify the changes in catchment sediment runoff from all 17 subcatchments under changing landuse and climate. The sediment load to the harbour from any given subcatchment increases with the area of the subcatchment. Most of the sediment discharged to the southern harbour enters from the Wairoa River subcatchment (45.6% of the total load to the southern harbour). While uncontrolled earthworks have high sediment yield, existing and planned controls on urban earthworks were predicted to reduce the sediment yield markedly. By the year 2051, the mean annual sediment load to the harbour was predicted to decrease slightly (by about 1%) because pasture landuse will be replaced by lower-yielding urban landuse. The contribution from urban earthworks was predicted to decrease over time because the rate of urbanisation is predicted to decrease in the future. Landuse changes other than urbanisation were not assessed in this study. Future climate change was predicted to increase the sediment load to the harbour by 42.8% by 2051. Averaged over the period from the present until 2051, climate change was predicted to increase the sediment load by 19.8%.

The model predictions quantify the changes in sedimentation rates for all 26 subestuaries in response to changing landuse and climate. Present-day sedimentation rates within the southern Tauranga Harbour are elevated where sediments are trapped along the fringes of larger embayments (e.g., Welcome Bay), in sheltered embayments at river mouths (e.g., Pahoia and Wainui), and where flushing is obstructed by causeways (e.g., Te Puna inner). Model predictions show that sedimentation will slightly reduce in line with the slight reductions in catchment sediment runoff under landuse change. In contrast, increases in catchment sediment runoff will cause even larger increases in sedimentation rate in most subestuaries. This nonlinear response is due to the overwhelming of harbour “self-cleansing” processes by the increased sediment runoff.

Assessment of options for management was made by integrating the model predictions with information that emerged during an expert panel workshop. Subestuaries with a high potential for adverse ecological effects were identified as 1–Speedway, 2–Rangataua Bay, 3–Welcome Bay, 4–Waimapu, 7–Waikareao, 9–Waikaraka, 10–Te Puna outer and 12–Waipapa. Subcatchments with a high potential for mitigation were 104–Waitao, 105–Kaitemako and 106–Waimapu. The seven subcatchments where mitigation efforts are optimal (i.e., applied in situations where the potential for adverse effects in receiving subestuaries is high, and the opportunity for mitigation in the subcatchment is high/medium) were identified as 104–Waitao, 105–Kaitemako, 106–Waimapu, 107–Kopurererua, 109–Oturu, 110–Te Puna and 112–Waipapa. Interventions in these subcatchments are likely to reduce sedimentation impacts in the subestuaries 1–Speedway, 2–Rangataua Bay, 3–Welcome Bay, 4–Waimapu, 7–Waikareao, 9–Waikaraka, 10–Te Puna outer and 12–Waipapa.

Key opportunities for mitigation include: (1) Retirement of steeper pasture areas or establishment of pine plantations on steep slopes is a mitigation option common to most subcatchments, and is expected to be effective in reducing sediment loads. (2) There are opportunities for enhanced floodplain deposition in the Waitao and Waimapu subcatchments. (3) There are opportunities for riparian planting in pasture areas in several subcatchments. (4) There are some minor opportunities where improved forestry controls would be beneficial. (5) Current earthworks controls should be maintained, but enhanced earthworks controls will give little additional benefit.

In general, sediment runoff mitigation in the catchment is preferable to reversal methods in the harbour, such as removal of mangroves and dredging.

1. Introduction

1.1 Background

In order to understand sediment sources and fate sufficiently to appropriately manage growth and development now and in the future Environment Bay of Plenty seeks to understand sedimentation in Tauranga Harbour. This knowledge will also assist Environment Bay of Plenty to adapt management rules and practices appropriately and enable decisions to be made concerning development of the harbour and catchment with full understanding of likely sedimentation effects. These requirements stem from section 5 of the Tauranga Harbour Integrated Management Study which describes the many effects of sediments. Although these changes are to a large extent driven by historical events during a period when there was little control on development, there is increasing public concern about sediment-related issues. These concerns are expected to escalate as the catchment continues to develop and the effects of climate change become increasingly felt. The Tauranga Harbour Integrated Management Study recommended a review of the drivers and consequences of sedimentation. This included an analysis of sediment yields from all sources in the catchment, peak flow monitoring, projection of sediment yields under proposed development scenarios, assessment of sediment effects in the harbour including cumulative effects, analysis of current best practices for sediment management and recommendations on how to address the findings, including appropriate policy.

Environment Bay of Plenty contracted NIWA to conduct the Tauranga Harbour Sediment Study. The study began in April 2007 and was scheduled to run for 3 years. The main aim of the study was to develop a model or models to be used to: (1) assess relative contributions of the various sediment sources in the catchment surrounding Tauranga Harbour, (2) assess the characteristics of significant sediment sources, and (3) investigate the fate (dispersal and deposition) of catchment sediments in Tauranga Harbour. The project area is defined as the southern harbour, extending from Matahui Point to Rangataua Bay in the south. The timeframe for predictions is 50 years from the present day (defined in this study as 2001).

1.2 Study outline and modules

The study consists of 6 modules:

Module A: Specification of scenarios – Defines landuse and weather information that is required for driving the various models. Three scenarios are defined in terms of landuse, which includes earthworks associated with any development, and weather.

Reported in:

Parshotam, A.; Hume, T.; Elliott, S.; Green, M. & Wadhwa, S. (2008). Tauranga Harbour Sediment Study: Specification of Scenarios. NIWA Client Report HAM2008–117, prepared for Environment Bay of Plenty, August 2008. 14 pp.

Module B: Catchment sediment modelling – (1) Uses the GLEAMS model to predict time series of daily sediment runoff from each subcatchment under each scenario. (2) Summarises these predictions to identify principal sources of sediment in the catchment, to compare sources of sediment under present-day landuse and under future development scenarios, and to assess characteristics of significant sediment sources. (3) Provides sediment loads to the USC-3 model for prediction of harbour sedimentation.

Reported in:

Parshotam, A.; Wadhwa, S. & Mullan, B. (2009). Tauranga Harbour Sediment Study: Sediment Load Model Implementation and Validation. NIWA Client Report HAM2009–007, prepared for Environment Bay of Plenty, March 2009. 103 pp.

Elliott, A.; Parshotam, A. & Wadhwa, S. (2009). Tauranga Harbour Sediment Study, Catchment Model Results. NIWA Client Report HAM2009–046, prepared for Environment Bay of Plenty, April 2009 (amended May 2010). 36 pp.

Module C: Harbour bed sediments – (1) Develops a description of the harbour bed sediments to provide sediment grainsize and composition information required for running the harbour sediment-transport model and for initialising the USC-3 model. (2) Provides information on sedimentation rates over the past 50 years for end-of-chain model validation.

Reported in:

Hancock, N.; Hume, T. & Swales, A. (2009). Tauranga Harbour Sediment Study, Harbour Bed Sediments. NIWA Client Report HAM2008–123, prepared for Environment Bay of Plenty, March 2009. 65 pp.

Module D: Harbour modelling – (1) Uses the DHI FM (Flexible Mesh) hydrodynamic and sediment models and the SWAN wave model to develop predictions of sediment dispersal and deposition at the “snapshot” or event scale, including during and between rainstorms and under a range of wind conditions. (2)

Provides these event predictions to the USC-3 model for prediction of harbour sedimentation.

Reported in:

Pritchard, M. & Gorman, R. (2009). Tauranga Harbour Sediment Study, Hydrodynamics and Sediment Transport Modelling. NIWA Client Report HAM2009–032, prepared for Environment Bay of Plenty, February 2009. 54 pp.

Module E: USC-3 model – Uses the USC-3 model to make predictions of sedimentation, bed-sediment composition and linkages between sources and sinks, based on division of the catchment into subcatchments and the estuary into subestuaries. An end-of-chain model validation consists of comparison of USC-3 model hindcasts of annual-average sedimentation rate to measured rates, where the measurements derive from Module C.

Reported in:

Green, M.O. (2009a). Tauranga Harbour Sediment Study: Implementation and Calibration of the USC-3 Model. NIWA Client Report HAM2009–038, prepared for Environment Bay of Plenty, May 2009. 71 pp.

Green, M.O. (2009b). Tauranga Harbour Sediment Study: Predictions of harbour sedimentation under future scenarios. NIWA Client Report HAM2009–078, prepared for Environment Bay of Plenty, June 2009 (amended May 2010). 63 pp.

Module F: Assessment of predictions for management – Assesses and synthesises information developed in the modelling components of the study using an expert panel approach. It addresses matters including: (1) Which catchments are more important as priority areas for focusing resources to reduce sedimentation in the harbour? (2) What are the likely effects of existing and future urban development on the harbour? (3) How can the appropriate regulatory agencies (Environment Bay of Plenty, Western Environment Bay of Plenty District Council, and Tauranga City Council) most effectively address sedimentation issues, and what management intervention could be appropriate? (4) Are there any reversal methods, such as mangrove control and channel dredging, that may be effective in managing sedimentation issues?

Reported in this report:

Hume, T.M.; Green, M.O.; Elliott, S. (2009). Tauranga Harbour Sediment Study: Assessment of predictions for management. NIWA Client Report HAM2009–139, prepared for Environment Bay of Plenty, December 2009 (amended May 2010). 116 pp.

1.3 Subestuary and subcatchment nomenclature

For the purpose of this study the southern Tauranga Harbour and contributing catchments were subdivided into 26 subestuaries and 17 subcatchments, respectively. **Subestuaries** are defined as km-scale compartments in the harbour with common depth, hydrodynamic exposure and bed-sediment grainsize. These are the fundamental units at which predictions are made by the harbour sedimentation model. **Subcatchments** are defined as km-scale compartments in the catchment that channel water and sediment to the subestuaries. Their boundaries are defined based on topography, supplemented with information on the urban drainage network in some places.

The subestuaries and subcatchments are identified in Figures1.1 and 1.2 and in Tables 1.1 and 1.2.

Table 1.1: Subestuary names and abbreviations (see Fig. 1.1).

Code	Subestuary
1 – SPW	Speedway
2 – RNC	Rangataua Bay
3 – WEL	Welcome Bay
4 – WMA	Waimapu
5 – TAC	Tauranga City foreshore
6 – WPB	Waipu Bay
7 – WKE	Waikareao
8 – WAR	Mouth of Wairoa River
9 – WKA	Waikaraka
10 – TPO	Te Puna (outer)
11 – MGO	Mangawhai Bay (outer)
12 – WAI	Mouth of Waipapa River
13 – PAH	Pahoia Beach Road
14 – WNR	Mouth of Wainui River
15 – AGR	Mouth of Aongatete River
16 – MHR	Middle-harbour sandbanks
17 – MKI	Matakana Island
18 – RGI	Rangiwaea Island
19 – HCK	Hunters Creek
20 – MGI	Mangawhai Bay (inner)
21 – OIK	Oikimoke Point
22 – MOT	Sandbank east of Motuhoa Island
23 – OMO	West of Omokoroa Peninsula
24 – OMI	Sandbank east of Omokoroa Peninsula
25 – MAT	Matua
26 – TPI	Te Puna (inner)
27 – SPO	Ocean
28 – DCS	Deep channel south
29 – DCC	Deep channel central
30 – DCN	Deep channel north

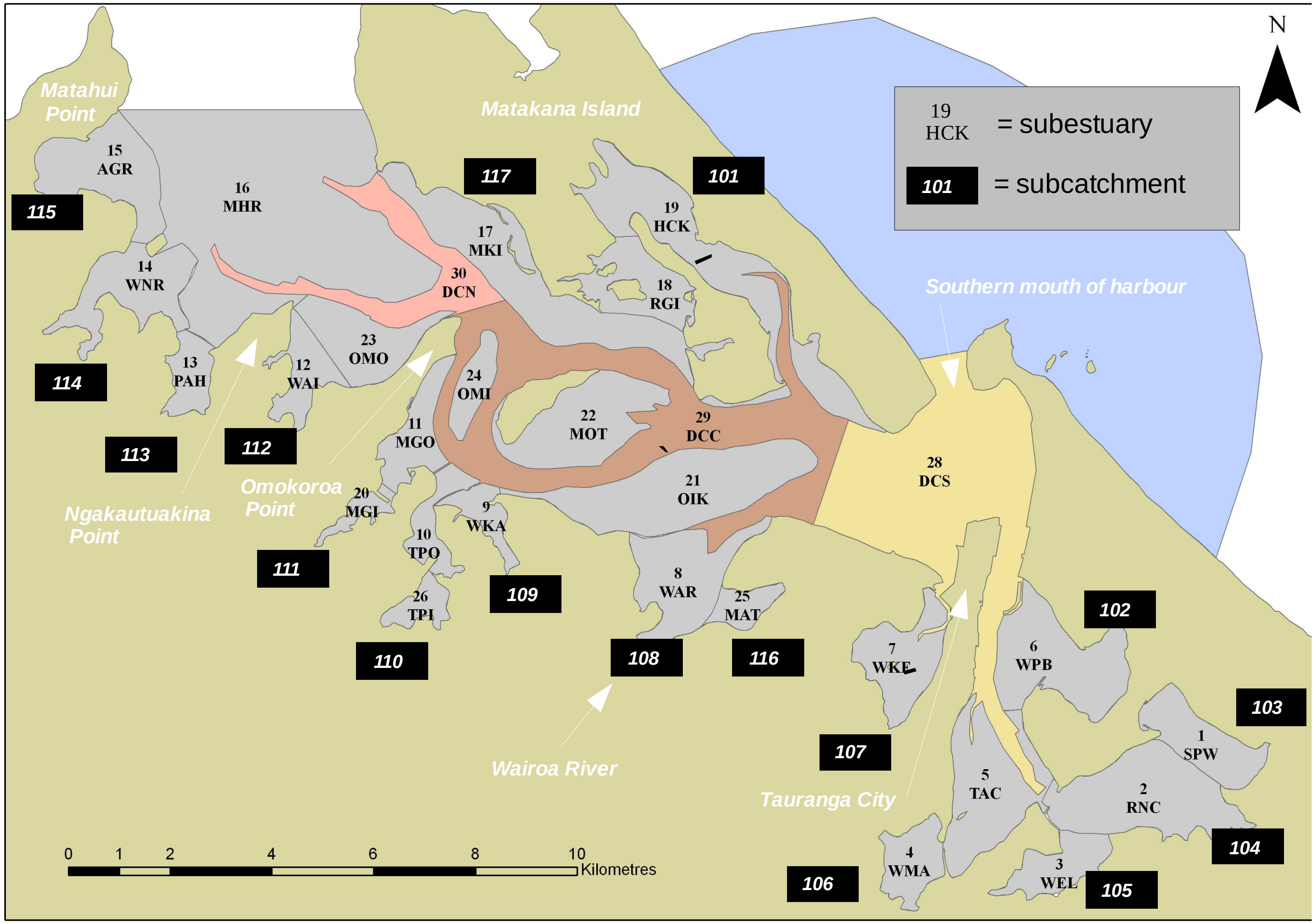

Figure 1.1: Subdivision of the southern Tauranga Harbour into subestuaries and the association of subcatchments with subestuaries. The black numbers are the subestuary numbers. The white numbers in the black boxes are the subestuary numbers.

Table 1.2: Subcatchment codes and abbreviations (see Fig. 1.2).

Code	Subcatchment
101 – MKE	Matakana 1
102 – MMI	Mount Maunganui
103 – PAP	Papamoa
104 – WTO	Waitao
105 – KMK	Kaitemako
106 – WMP	Waimapu
107 – KOP	Kopurererua
108 – WAR	Wairoa
109 – OTU	Oturu
110 – TPU	Te Puna
111 – MGW	Mangawhai
112 – WAI	Waipapa
113 – APA	Apata
114 – WNR	Wainui
115 – AGR	Aongatete
116 – MAT	Matua
117 – MKW	Matakana 2

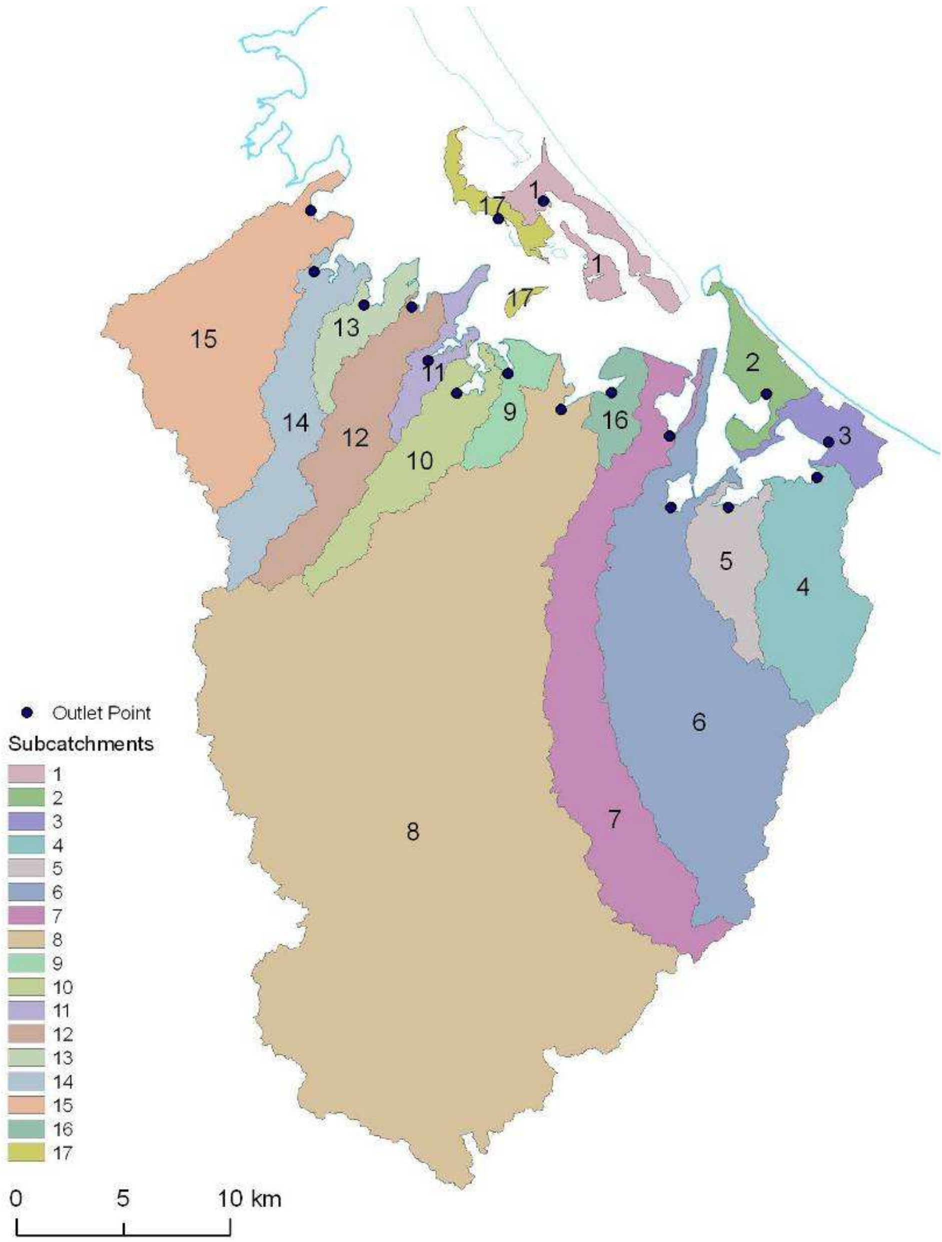

Figure 1.2: Location of subcatchments draining to southern Tauranga Harbour.

1.4 This report

This report is Technical Report F1 of Module F of the Tauranga Harbour Sediment Study, and along with the workshop, completes contract Milestones M11 and 12.

It addresses the four questions described in Module F through a synthesis of information that emerged during expert panel discussions at the workshop and information contained in the technical reports of the Tauranga Harbour Sediment Study.

2. The assessment of predictions for management workshop

The Assessment of Predictions for Management Workshop was convened at Environment Bay of Plenty's Mt Maunganui offices on 13 July 2009. The expert panel included participants from NIWA, Environment Bay of Plenty, Tauranga City Council, and Western Bay of Plenty District Council. The workshop undertook an analysis of the issues and mitigations options possible in the context of the catchment sediment runoff and estuary sedimentation predictions previously reported.

Information that emerged from the workshop, including presentations and findings, is summarised in Appendix 6.1.

The workshop process revealed that the key findings of the Tauranga Harbour Sediment Study provided very specific and quantitative advice regarding sediment runoff to southern Tauranga Harbour. The Study also quantified how sediment is dispersed and deposited throughout the harbour, both now and in the future under landuse and climate change scenarios. It found that the results were provided at useful management scales (subcatchment and subestuary spatial scales; annual and decadal temporal scales). It revealed that ranking the subestuaries in terms of their potential for mitigation success is potentially a useful tool. This method is developed further in this report.

The Study found that the manner in which subestuaries respond to sediment inputs is not always intuitive, particularly when various climate-change factors are considered. While some subcatchments deliver substantial amounts of sediment to the harbour, considerable proportions of the input sediment can bypass to the ocean; some sediment gets shunted into other subestuaries; and some gets resuspended by wind waves after initial settlement and moved to other subestuaries. The overall result is that the source of sediment in any given subestuary may not necessarily be the adjacent subcatchment.

The decision making process involving consideration of catchment runoff, how the subestuary responds to inputs, and weighing up of the options for sediment mitigation/intervention in the catchment and/or estuary, was quite complex. It required a thorough understanding of the manner in which sediment is shunted around, and settled in, the estuary. Making good decisions on options for sediment mitigation/intervention therefore requires integration of knowledge of estuary processes, catchment processes at a local (on the ground) level, planning and consenting issues, and practical and financial constraints both in the catchment and estuary. Not all this information was held by the experts during the workshop, and so some of the analysis captured here is preliminary. However, the process we went through reinforced the value of a workshop approach in which experts and practitioners from several disciplines bring their knowledge to the table and debate the issues, actions and consequences.

A further consequence of the complexity of the processes operating in the harbour is that management decisions will need to be accompanied by simple explanations of complex processes in order to justify those decisions to the public.

Throughout the Study, and specifically in the workshop, we identified key knowledge gaps that could be used to guide and optimise further investigations and to identify areas where monitoring in the estuary and catchment should begin, stop or be strengthened. For instance, improvement in the understanding of sediment loads to the estuary could include: assessment and modelling of stream bank erosion; continued collection of longer-term monitoring data to better characterise the distribution of event sediment loads and the relation between rainfall and loads; comparison of predicted and measured stream sediment loads; assessment of current and future prevalence of slips in the catchment; and further monitoring to refine model parameters related to the effects of landuse.

3. Assessment of predictions for management

This section provides an assessment of predictions for management by integrating the information that emerged during the workshop with the catchment and harbour sediment modelling results. It does this in a systematic manner for each subcatchment and subestuary using datasheets. It effectively links "subestuary effects" to "subcatchment causes", thereby identifying where best management practices on the land could be most effectively focused. It presents rankings that identify the potential scale of adverse effects in each subestuary, and the potential mitigation options/opportunities in each subcatchment. It summarises and distils a very large amount of detail into a series of tables to pinpoint:

- Those subestuaries that have the greatest potential for adverse effects under the combined influence of landuse (as defined by SmartGrowth) and climate change over the next 50 years.

- Those subcatchments that are priority areas where resources should be focused to reduce sedimentation in the harbour.

- Those management interventions that would most effectively address sedimentation issues.

Other matters such as the merits of various mitigation opportunities in the catchment, and whether there are any reversal methods in the harbour (such as mangrove control and channel dredging) that may be effective in managing sedimentation issues, are commented on.

3.1 Summary of effects of landuse and climate change in subestuaries

Tables are produced in Appendix 6.2 that summarise for each of the **26 subestuaries** sources of catchment-derived sediment. The tables show, for both the landuse and climate change scenarios, how the annual-average fine-sediment runoff from the largest source catchment will change, how the annual-average fine-sediment accumulation rate (mm/yr) will change, and the potential scale (low, medium and high) of adverse ecological effects.

The primary fate of fine sediment discharged from each subcatchment and the principal sources of fine sediment deposited in each subestuary are mapped in Figures 3.1 and 3.2, respectively.

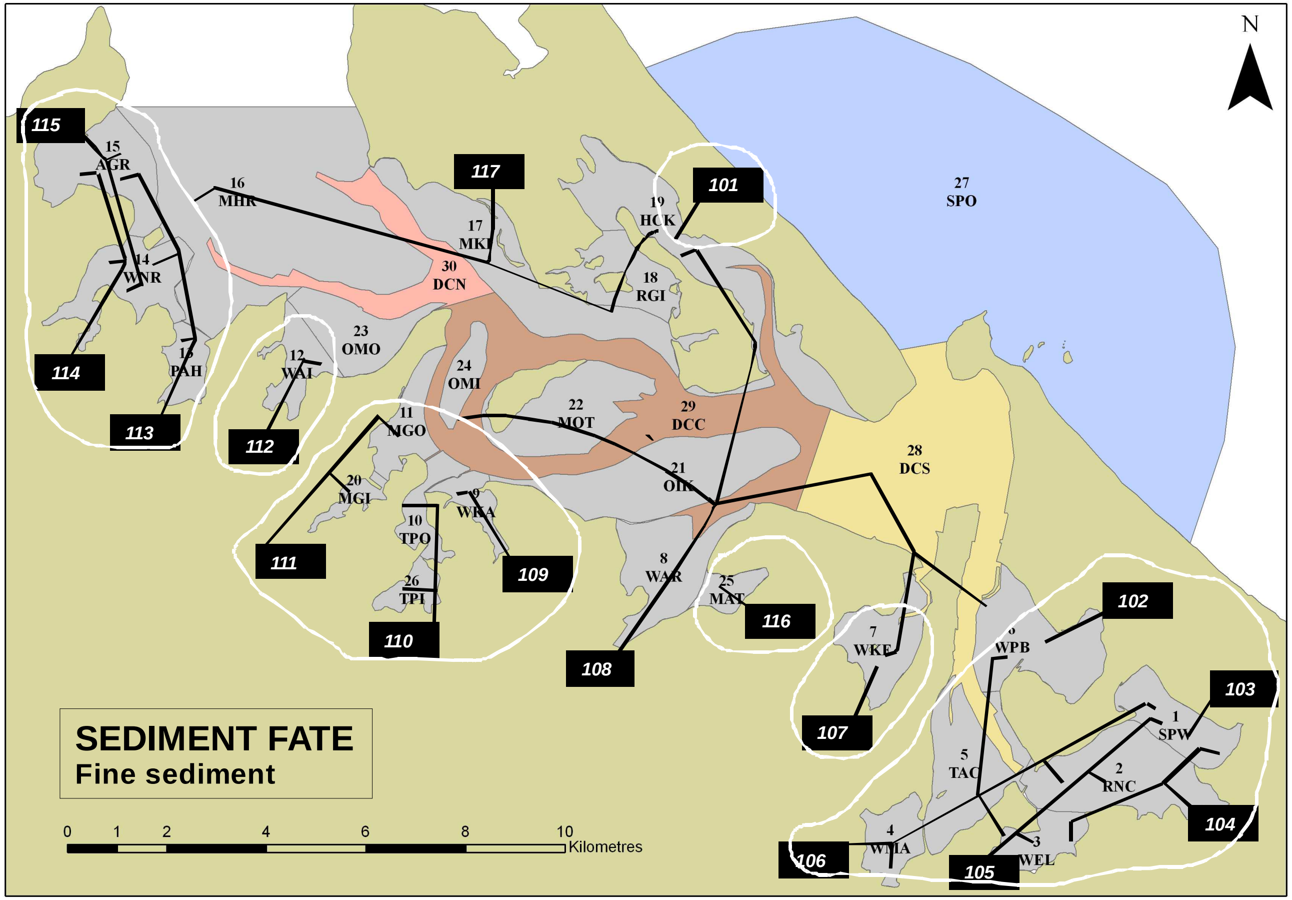

Figure 3.1: Primary fate of fine sediment discharged from each subcatchment. The black numbers are the subestuary numbers. The white numbers in the black boxes are the subcatchment numbers. The black lines connect with the subestuaries where sediment from each subcatchment is deposited. These are broad patterns, applicable to every scenario. These can be thought of as primary transport pathways for terrigenous fine sediment that result in deposition. (Note that the lines simply connect source and sink; they do not imply an actual route the sediment follows between source and sink). Not shown is loss of sediment to the coastal ocean.

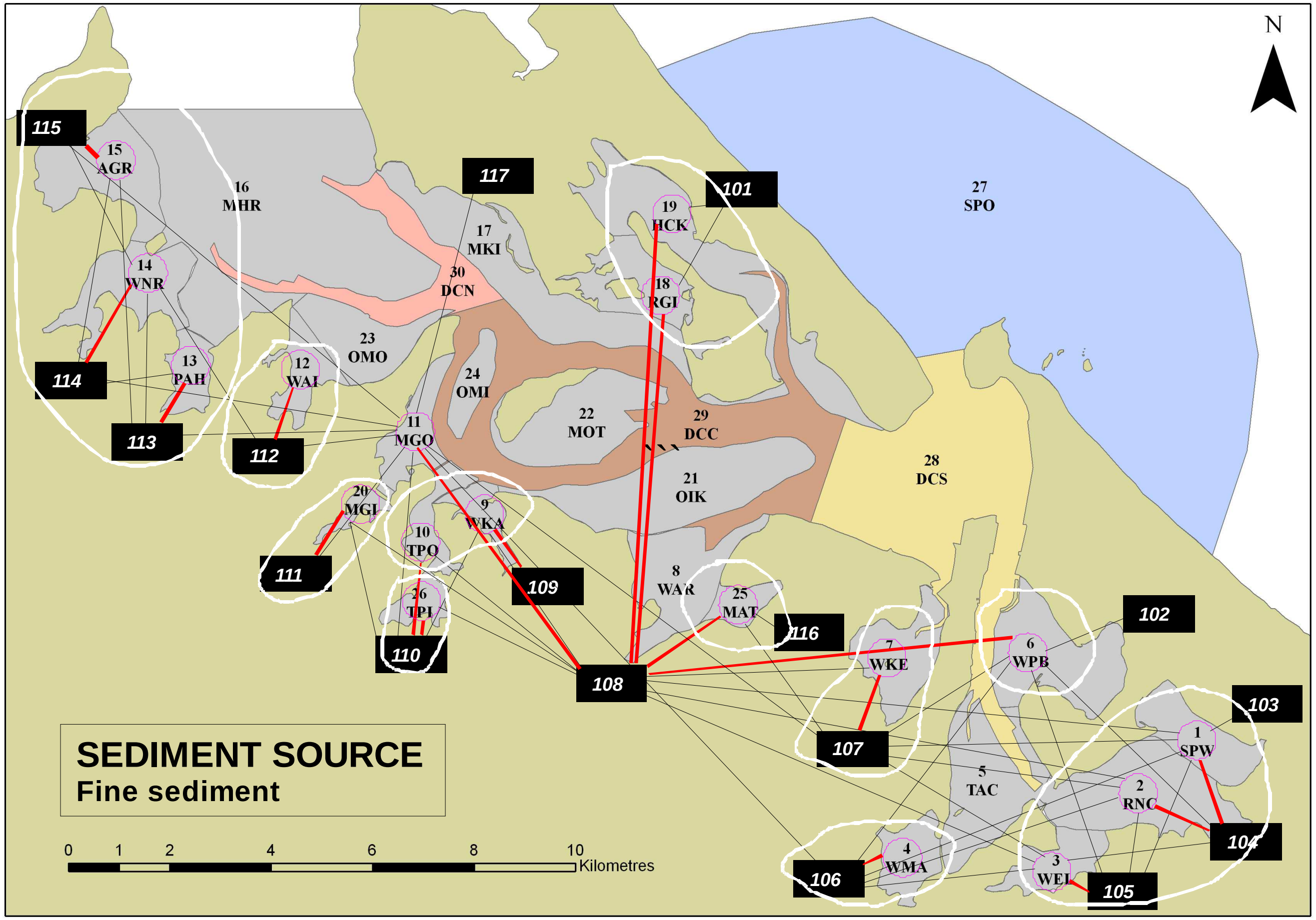

Figure 3.2: Principal sources of fine sediment deposited in each subestuary. The black numbers are the subestuary numbers. The white numbers in the black boxes are the subcatchment numbers. These are broad patterns, and they apply to every scenario. There is one thick, red line that connects each subestuary to a subcatchment. This denotes the principal source of sediment to that subestuary. The thin, black lines that connect to other subcatchments show secondary sources. The white ovals group subestuaries with common sediment sources.

Key findings are summarised here to provide background explanation for the information in Appendix 6.2:

- Present-day sedimentation rates are elevated where sediments are trapped along the fringes of larger embayments (e.g., Welcome Bay), in sheltered embayments at river mouths (e.g., Pahoia and Wainui), and where flushing is obstructed by causeways (e.g., Te Puna inner).

- Fine-sediment loss to the ocean is greatest from those subcatchments that discharge close to the (southern) mouth of the harbour. Nearly all (95%) of the fine sediment discharged from Wairoa River, which has the largest freshwater discharge and sediment runoff of any subcatchment, is lost to the ocean. The loss of coarse sediment to the ocean is much smaller because the coarser sediment grains are heavier, and therefore less easily dispersed and resuspended by waves and currents. They therefore tend to settle close to their respective stream source.

- In general, there does not exist an exact correspondence between change in sedimentation rate in any given subestuary and change in sediment runoff from the subcatchment that is the largest source of sediment to that subestuary. There are two reasons for this. Firstly, subestuaries typically receive and deposit sediment from more than one subcatchment, and the changes in sediment runoff under the various scenarios are usually different for each subcatchment. Secondly, the patterns of sediment transport in the harbour can be changed by changes in sediment runoff from the catchment, which can alter the relationships between sources and sinks.

- Landuse change will typically result in small or zero reduction in sediment runoff. Sedimentation will slightly reduce in line with the slight reductions in catchment sediment runoff under landuse change.

- In contrast, climate change is predicted to increase sediment runoff from every subcatchment.

- Under climate change, increases in catchment sediment runoff will cause even larger increases in sedimentation rate in most subestuaries. This nonlinear response is due to the overwhelming of harbour “self-cleansing” processes by the increased sediment runoff.

- For all subestuaries, climate change will be the dominant driver of change (as opposed to landuse change).

- The seabed composition will become progressively finer where fine sediments deposit on a relatively coarser pre-existing bed.

Those subestuaries where the ecology is at risk due to fine-sediment deposition are mapped in Figure 3.3.

- The predicted fine-sediment sedimentation rate under the combined influence of landuse change and climate change (i.e., Scenario 3) is scaled such that a high sedimentation rate is >1.0 mm/year, a moderate sedimentation rate is 0.30–1.0 mm/year and a low sedimentation rate is <0.30 mm/year.

- Present-day mud content is scaled as high (>20%), moderate (10–20%) and low (<10%).

- The greatest potential for adverse effects will occur where a high fine-sediment sedimentation rate combines with an already-low seabed mud content. This will cause the bed to become muddier, which will cause adverse ecological effects. Conversely, a high fine-sediment sedimentation rate combined with an already-high mud content may cause only minor ecological effects, because the benthic biota is already adapted to the presence of mud.

- Following this kind of reasoning, the ranking in Figure 3.3 roughly indicates those parts of the harbour where the ecology may be at risk due to fine-sediment deposition.

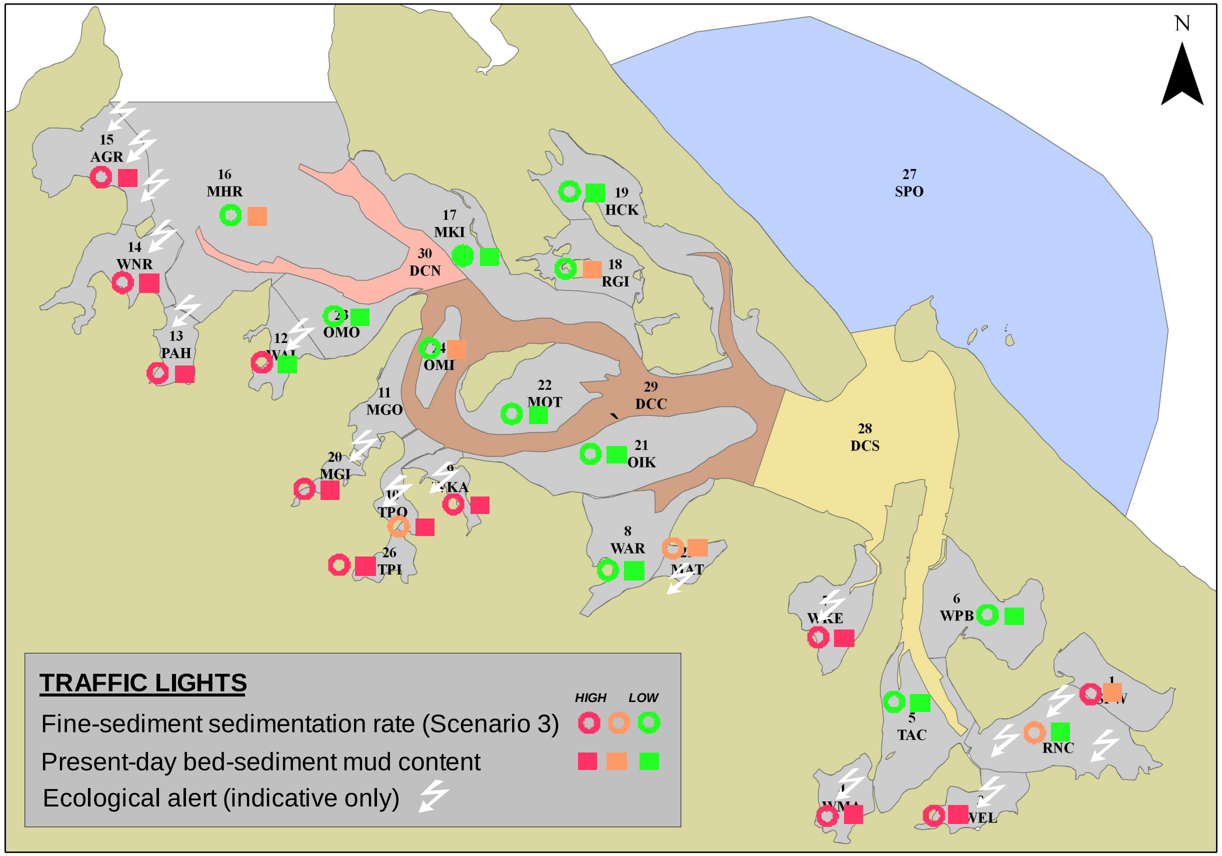

Figure 3.3: Fine-sediment sedimentation rate under the combined influence of landuse change and climate change (i.e., Scenario 3) classified using a "traffic light" system: red signifies a high sedimentation rate (>1.0 mm/year); amber signifies a moderate sedimentation rate (0.30–1.0 mm/year); and green signifies a low sedimentation rate (<0.30 mm/year). The present-day mud content of the bed is also shown, classified using "traffic lights": red signifies high mud content (>20%); amber signifies moderate mud content (10–20%); and green signifies low mud content (<10%). "Ecology alerts" very roughly indicate parts of the harbour where the ecology may be at risk due to fine-sediment deposition. The black numbers are the subestuary numbers.

3.2 Merits of reversal methods in the harbour to address sedimentation issues

As a general rule, mitigating sediment runoff in the catchment is preferable to reversal methods in the harbour such as mangrove control and channel dredging.

(a) Mangrove control

Removal of mangroves has been used with success in Tauranga Harbour to provide more open space and reduce the build up of muddy sediments as part of estuary restoration. Further consents have been acquired to expand these activities in areas where Estuary Care groups are active.

Mangroves reduce tidal-current and wind-wave stirring of the seabed, thereby enhancing settlement of fine sediment. This further increases the extent of habitat suitable for mangrove colonisation, resulting in something of a "positive feedback". Removing mangroves allows currents to rework the seabed with increased energy (no longer damped by the mangrove forest), resuspending sediment that is in turn dispersed. The dispersed sediment ultimately resettles within the harbour, or is flushed to the ocean. The map of sediment fate (Fig. 4.3, in Green 2009b) indicates where this sediment may be dispersed to.

Removal of mangroves requires a coastal permit under the Resource Management Act 1991, and is a discretionary activity under the Bay of Plenty Regional Coastal Environment Plan. There are already permits in place to provide for the manual removal of mangrove plants from designated areas within Tauranga Harbour. Recently, a coastal permit was granted to allow mechanical removal of up to 92 hectares of mangroves. Environment Bay of Plenty intends to use a machine with low ground pressure and a mulching unit attached to clear the mangroves. The machine exerts approximately 2 psi ground pressure, significantly less than a human footprint. The mechanical removal will occur in areas where consents exist for mangrove removal by 10 Estuary Care groups across Tauranga Harbour.

(**b) Dredging**

Dredging of subestuaries to remove accumulated fine sediment has received little consideration to date.

Fine sediment generally accumulates in intertidal areas. These are dry for much of the tidal cycle, and shallow when the tide is full, which limits equipment access both from land and sea. In addition, the ground will be soft and not easily accessible by tracked vehicles. The dredged sediment is likely to be very fluid and difficult to transport and dispose of. The act of dredging can generate high levels of suspended solids that will be dispersed to other areas. The cost of these operations will be high. Consents will be required for these operations.

Given these issues, dredging is not recommended.

3.3 Summary of effects of landuse and climate change in subcatchments

Tables are produced in Appendix 6.3 that summarise, for each of the **17 subcatchments**, the quantity of sediment runoff from the subcatchment that is lost to the ocean, a ranking in terms of overall fine sediment contribution to the southern harbour, the fraction of sediment from the subcatchment that is deposited in neighbouring subestuaries, sediment load and yield from the subcatchment (t/y and t/ha/yr), the landuse, soil and slope characteristics, and various mitigation options and opportunity to undertake them and their effect.

Key findings are summarised here to provide background explanation for the information in Appendix 6.3.

- Land slope, soil type, rainfall, and landuse all have a significant impact on sediment yields, which leads to a complex spatial pattern of sediment generation. The highest yields occur for pasture areas, steep slopes, and soils which are less well-drained.

- Pasture, which covers 33.7% of the catchment, makes the largest contribution to the sediment load from the catchment (62.5% of the total in tonnes per year, t/yr). Although bush, scrub and native forest cover 43.9% of the catchment and are generally in steeper, higher-rainfall parts of the catchment, they contribute only 27.3% of the total sediment load.

- Uncontrolled earthworks have high sediment yield (yields are in tonnes per hectare per year, t/ha/yr). However, controls on urban earthworks were predicted to reduce the sediment yield markedly. Such controls, in conjunction with the small areas of urban earthworks, were predicted to reduce the sediment load (t/yr) from earthworks to 0.5% of the total load to the estuary.

- Orchards and cropland were predicted to make a small contribution to the sediment load to the estuary. Bare earth associated with cropland makes only a small contribution to the total sediment load, because the areas are small.

- In general, the sediment load to the harbour from a subcatchment increases with the area of the subcatchment. Most of the sediment entering the southern harbour enters through the Wairoa subcatchment (45.6% of the total load to the southern harbour). The Matakana 1 subcatchment has the lowest yield, due to the pine forest landuse and well-drained soils. The Apata subcatchment has highest yield, due to the pasture landuse, moderate slopes, and moderate rainfall.

- By the year 2051, the mean annual sediment load to the harbour with the current climate was predicted to decrease slightly because pasture landuse will be replaced by lower-yielding urban landuse. Landuse changes other than urbanisation were not assessed in this study. The contribution from urban earthworks was predicted to decrease over time from the current level of 0.5%, because the rate of urbanisation is predicted to decrease in the future. Future climate change was predicted to increase the sediment load to the harbour by 42.8% by 2051. Averaged over the period from the present until 2051, climate change was predicted to increase the sediment load by 19.8%.

3.4 Mitigation opportunities in the subcatchments

(a) Urban earthworks controls

The catchment model predicted that urban earthworks make a relatively small contribution (<1%) to the total sediment load to the harbour. This is because urban earthworks are generally on flatter areas, at any time earthworks comprise a small proportion of the catchment, and earthworks controls are used routinely to manage and reduce sediment loads. The contribution from earthworks will decrease over time, as the rate of urbanisation will decrease under the planned SmartGrowth development. In some subcatchments, such as the Kaitemako, the urban earthworks area is a larger proportion of the catchment, averaged over a decade, but even so is still a small proportion of the catchment (approximately 1% at current urbanisation rates) and the proportion of sediment load attributable to urbanisation is relatively small compared with the sediment yield from the rest of the catchment. The model predictions of a relatively small contribution to the total sediment load to the harbour are backed up to some degree by limited measurements during a storm event in the Kopurererua during the earthworks phase of a large development. Monitoring results did not show a large signal of additional sediment yield from the earthworks (Elliott et al. 2009).

Earthworks in the catchment are controlled under the Erosion and Sediment Control Guidelines (Environment BOP 2001). There seems to be widespread compliance with these guidelines in urban earthworks areas. These controls are expected to effectively control sediment loads; without them, earthworks would make a minor but not insignificant contribution to the sediment load in some subcatchments. Therefore, ongoing application of the controls is encouraged. While more stringent controls could be introduced, such as the use of flocculation ponds, this is probably not warranted except in exceptional circumstances (for example, to protect highly sensitive wetland areas), because urban earthworks make a relatively small contribution.

Increased storminess accompanying climate change will likely reduce the trapping efficiency of sediment retention ponds marginally, but the sensitivity of removal efficiency to storm size is not expected to be large, so that there is little requirement to increase pond size to account for increased volumes of water entering the ponds. General increases in sediment load from the catchments in response to climate change would be of more concern than the effect of climate change on pond performance.

(b) Land retirement

Retirement of steep, grazed pasture is likely to reduce sediment yield by a factor of 5 to 10 times, as indicated by the model and as attested by several studies in New Zealand (e.g., Blaschke et al. 2008). Retirement of steep pasture areas would reduce sediment load more than retirement of areas of lower slope. For example, the model indicates that steep pasture areas (with slope greater than 20 degrees) are about 2.3% of the catchment, but contribute about 21% of the sediment load to streams. Hence, retirement targeted at steep pasture areas is likely to be cost-effective compared with un-targeted retirement. While a considerable amount of steep land in the catchment has already been retired or put into pine plantation, significant opportunities for retirement remain.

Although closely-spaced pole planting will be effective for reducing erosion, it will not be as effective as complete land retirement or re-planting, because a sheet erosion component associated with grazing will remain. Pole planting does not seem to be used much in the catchment at present, perhaps because mass erosion is not a common feature and pole planting is intended primarily for the control of unstable land.

(c) Pine plantation establishment

Pine plantations reduce erosion compared with pasture, and mature pines have a sediment yield similar to that of native bush (e.g., Blaschke et al. 2008). In the harvesting period, sediment yields can increase considerably, to values higher that for pasture, but the yields return to background levels within a few years. Most of the yield is associated with mass failures such as collapse of road embankments, rather than from sheet flow. There are some opportunities for pine plantation in the catchment, and some areas of pasture have been put into pines historically already (10.2% of the catchment). It would not be practicable to target steep slopes solely for forestry, because the distribution of steep areas is patchy. A financial viable forestry block would cover a range of slopes.

(d) Forestry controls

Considering that most sediment from forestry is released during the harvesting phase, controls on erosion during this phase are important. Over time, forestry practices have improved, and this is likely to have reduced sediment loads associated with the harvesting phase (pers. comm. Chris Phillips, Landcare Research).

Controls are particularly important on steep areas, as these are likely to involve more roading and more potential for erosion relative to flatter areas. Such steep pine forested areas constitute only 1.3% of the catchment, but would contribute a disproportionate amount of the harvesting-associated sediment. Buffers reduced the extent of stream erosion features in recently-harvested forest at Whangapoua (Boothroyd et al. 2004), indicating that buffer retention or establishment is worthwhile.

According to the model, mature forest contributes 3.7% of the sediment load. The specific contribution of the harvesting phase to overall sediment loads is difficult to quantify from the model, because the processes of erosion associated with harvesting are not represented well within the model. Assuming that harvesting doubles the sediment load compared with mature forest, averaged over a harvesting cycle (e.g., Hicks and Harmsworth 1989; Fahey et al. 2008), we can expect that harvesting would contribute 3.7% of the sediment load. If additional controls were introduced, this may decrease the contribution from harvesting to 1.8%. There are some subcatchments where forestry covers a larger part of the catchment, particularly in the Waitao catchment (17.5% of the catchment), so careful forestry practices would likely reduce the sediment load.

(f) Riparian planting

While many of the stream banks are in bush areas or have riparian protection, there are some unprotected banks in pasture areas scattered throughout the catchment. These offer opportunities for additional protection, as noted in the tables in the appendices. In many places the streams have become entrenched down to a rock or relatively stable gravel base (Surman et al. 1999). A considerable proportion of the streams are in gullies with steep and vegetated banks, offering little extra opportunity for riparian protection. While localised bank erosion occurs in the vicinity of obstructions such as willows, this form of localised erosion is not likely to cause significant increases in sources of sediment to the estuary.

The contribution of bank erosion to sediment sources in the catchment is difficult to quantify, and there is uncertainty among the scientific community as to the importance of bank erosion as a sediment source. In some areas, meandering streams might appear to be a source of sediment due to steep eroding outer banks, but experience at other North Island sites suggests that there is little net increase in stream planform because as the banks erode on the outside of stream channel the bars on the inside of bend accrete sediment. Also, while large storm events may remove small inset terraces, this may be counterbalanced by accretion of sediment during smaller storms. On the other hand, from our studies in the Waitetuna catchment near Raglan, unstable alluvial channels can be a significant source of sediment in moderately large storms. Also, land clearance has in some cases resulted in deposition of sediment and accretion of the stream and floodplain, and this material is now being re-worked, and it acts as an apparent source of sediment over decadal time-scales. As a broad indication, in North Island pasture streams, bank erosion may contribute 10% of the sediment load (pers. comm., John Dymond, Landcare Research). Generally-speaking, large areas of active alluvial material in the Tauranga catchments do not exist, and there is no evidence of gross and widespread downcutting, widening, or gullying at present. Nevertheless, considering that riparian planting provides co-benefits such as stream shading, stock exclusion, and landscape enhancement, while riparian protection may result in some reduction in sediment loads, riparian planting in remaining pasture areas with unstable banks should be encouraged.

(g) Enhanced floodplain deposition

This control measure seeks to increase the frequency of flows onto floodplains by restricting flows in the main channel. In principle, this will enable more sediment to deposit on floodplain areas. While silt deposition on floodplains is a natural phenomenon, enhancement of this process is a fairly novel idea. The efficacy of such measures is also uncertain. However, as a rough indication, a ponding/floodplain area in the order of 1% of the catchment may be required to achieve a sediment load reduction of 50% (e.g., Barskerud 2001). This is a substantial area, which would need to be in the lower, flatter parts of the catchments to avoid the use of high impoundment or flow-constriction structures. Examination of topography and landuse in the catchment identified that in many cases increased floodplain inundation in the lower catchment would be inconsistent with assets such as major roads, urban or periurban areas, or high-value landuses, and hence would be unpopular solutions. Further up in the catchments, where landuse is generally less intense, the topography is generally unsuitable for effective floodplain deposition (steeper streams, often gullied or confined, with small or no flood terraces). A potential opportunity was identified in the Waitao catchment, about 3 km from the coast, although there may be conflicts with flooding of farm houses and Waitao Rd. There are some potential ponding areas in the lower Omanawa (drains to the Wairoa), where the available area would amount to 0.5% of the catchment or less. There are some good opportunities in the Waiorohi catchment (tributary of the Waimapu).

Many of these findings are based on model predictions with limited calibration/validation, or on extrapolation of findings from other catchments. Further monitoring would improve the estimates of sediment sources and effectiveness of various mitigation measures. The following work is recommended:

- Further monitoring of sediment loads in catchments with various landuses to refine estimates of the contribution from various landuses.

- Continued collection of longer-term monitoring data to better characterise the relationship between rainfall and sediment loads (and climate change effects to be better evaluated).

- Further monitoring of the effects of urban earthworks and associated controls: while we conclude that earthworks make a small contribution to sediment loads, earthworks are highly visible and politically contentious, so that improved data are desirable.

- Further investigation of the feasibility and effectiveness of enhanced floodplain deposition.

- Measurement of rates of stream bank erosion.

- Testing and validation of stream transport components of the model.

We also recommend that the considerable quantity of data collated for the catchment model should be compiled and made accessible to those conducting detailed assessments of control measures.

3.5 Recommendations for management intervention

Table 3.1 ranks the scale of ecological effects (Low, Medium or High) in each of the subestuaries under the combined influence of landuse and climate change. It also ranks the potential for mitigation (Low, Medium or High) in each of the subcatchments. Table 3.1 integrates information in the subestuary and subcatchment summary tables (tables in Appendices 2 and 3).

The table is read as follows:

1) The top rows identify the subestuaries. The yellow, orange and red coloured cells rank the scale of ecological effects (Low, Medium or High) in each of the subestuaries resulting from sediment runoff under the combined influence of landuse (as defined by SmartGrowth) and climate change over the next 50 years. For example, Speedway subestuary has High potential for adverse ecological effects, while Te Puna subestuary has Low potential for adverse ecological effects.

2) The left hand columns identify the subcatchments. The white, light blue and dark blue coloured cells rank the potential for sediment mitigation measures (Low, Medium or High) in each of the subcatchments. Mitigation options include retirement or further conservation planting in erosion-prone pasture areas, pine plantation in steeper or erosion-prone pasture areas, riparian planting, enhanced floodplain deposition, forestry controls and urban earthworks controls. For example, Matakana subcatchment has Low potential for sediment mitigation measures, while Waitao subcatchment has High potential for sediment mitigation measures.

3) The numbers in the body of the table show the proportion (%) of fine sediments that a subcatchment provides to a subestuary (only those subcatchments contributing >5% are shown). For example, the Speedway subestuary receives sediment from the Papamoa (12%), Waitao (47%) and Waimapu (31%) subcatchments.

Table 3.1: Table ranking the scale of ecological effects (Low, Medium and High; yellow, orange and red) in each of the subestuaries resulting from sediment runoff in response to landuse and climate change. The table also ranks the potential for mitigation (Low, Medium and High; white, light blue and dark blue) in each of the subcatchments. The numbers in the body of the table show the proportion (%) of fine sediments that each subcatchment provides to each subestuary (only those subcatchments contributing >5% are shown). The subcatchments where opportunities for mitigation are high and where that mitigation will result in reduction of sediment deposition in subestuaries with high potential for adverse ecological effects are identified by the dark green coloured cells in the body of the table. The dark green cells indicate a higher priority for mitigation than the light green cells.

	Potential for mitigation in subcatchments	Subestuaries: 1 - SPW Speedway	2 - RNC Rangataua Bay	3 - WEL Welcome Bay	4 - WMA Waimapu	5 - TAC Tauranga City foreshore	6 WPB Waipu Bay	7 - WKE Waikareao	8 WAR Mouth of Wairoa River	9 - WKA Waikaraka	10 - TPO Te Puna (outer)	11 - MGO Mangawhai Bay (outer)	12 - WAI Mouth of Waipapa River	13 - PAH Pahoia Beach Road	14 - WNR Mouth of Wainui River	15 - AGR Mouth of Aongatete River	16 - MHR Middle-harbour sandbanks	17 - MKI Matakana Island	18 - RGI Rangiwaea Island	19 - HCK Hunters Creek	20 - MGI Mangawhai Bay (inner)	21 - OIK Oikimoke Point	22 - MOT - Sandbank E of Motuhoa Is	23 - OMO W of Omokoroa Peninsula	24 - OMI Sandbank E of Omokoroa Pen	25 - MAT Matua	26 - TPI Te Puna (inner)
Scale of adverse effects in subestuaries		H	H	H	H	L	L	H	L	H	H	M	H	M	M	M	L	L	L	L	L	L	L	M	L	L	L
101 - MKE Matakana Is.	L																										
102 - MMI Mount Maunganui	L						10																				
103 - PAP Papamoa	M	12																									
104 - WTO Waitao	H	47	79	21			5																				
105 - KMK Kaitemako	H			47																							
106 - WMP Waimapu	H	31	16	26	99		26																				
107 - KOP Kopurererua	M						7	82											5								
108 - WAR Wairoa	L	7		5			48	18		20		59							65	80	19					72	
109 - OUT Oturu	M									68																	
110 - TPU Te Puna	M									5	98																98
111 - MGW Mangawhai	M											24									67						
112 - WAI Waipapa	M												99						5								
113 - APA Apata	M													98													
114 - WNR Wainui	M														95												
115 - AGR Aongatete	M															97											
116 - MAT Matua	L																										
117 - MTW Matakana 2	L																										

The subcatchments where opportunities for mitigation are high and where that mitigation will result in reduction of sediment deposition in subestuaries with high potential for adverse ecological effects are identified by the dark green coloured cells in the body of the table. For example, there are very good opportunities for sediment load reduction in the Waimapu subcatchment. Since this subcatchment makes a significant contribution to sedimentation in the Speedway (31%) and Waimapu (99%) subestuaries, and since these two subestuaries at high risk, then the cell linking Waimapu subcatchment with Speedway subestuary, and the cell linking Waimapu subcatchment with Waimapu subestuary are coloured dark green. The dark green cells indicate a higher priority for mitigation than the light green cells.

(a) Effects in subestuaries

Subestuaries with a high potential for adverse ecological effects were identified as 1–Speedway, 2–Rangataua Bay, 3–Welcome Bay, 4–Waimapu, 7–Waikareao, 9–Waikaraka, 10–Te Puna outer and 12–Waipapa. This ranking is derived from Figure 3.3, which has been explained previously.

(b) Potential for mitigation in subcatchments

Seven high-priority subcatchments were identified: 104–Waitao, 105–Kaitemako, 106–Waimapu, 107–Kopurererua, 109–Oturu, 110–Te Puna and 112–Waipapa. Interventions in these subcatchments will reduce sedimentation impacts in the following subestuaries: 1–Speedway, 2–Rangataua Bay, 3–Welcome Bay, 4–Waimapu, 7–Waikareao, 9–Waikaraka, 10–Te Puna outer and 12–Waipapa.

Key opportunities for mitigation include: 1) Retirement of steeper pasture areas or establishment of pine plantations on steep slopes is a mitigation option common to most subcatchments, and is expected to be effective in reducing sediment loads. 2) Enhanced floodplain deposition in the Waitao and Waimapu subcatchments. 3) Riparian planting in pasture areas in several subcatchments. 4) Minor opportunities where improved forestry controls would be beneficial. 5) Current earthworks controls should be maintained, but enhanced earthworks controls will give little additional benefit. Subcatchment-by-subcatchment opportunities are presented in Appendix 3.

4. Acknowledgements

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6. Appendices

6.1 Appendix 6.1: Assessment of predictions for management workshop and presentations from the workshop

The workshop and participants

The Tauranga Harbour Sediment Study – Assessment of Predictions for Management Workshop was convened at Environment Bay of Plenty, Mt Maunganui offices on 13 July 2009. NIWA participants included Terry Hume, Mal Green, Sandy Elliott and Nicole Hancock. Environment Bay of Plenty participants included David Phizacklea, Rob Donald, Robyn Skelton, Simon Stokes, Aileen Lawrie, Daryll Hall, John Morris, Stephen Park, Dani Guinto and Dudley Clemens. In addition participants from Tauranga City Council (James Danby) and Western Bay of Plenty District Council (Glenys Kroon and Glenn Ayo) also attended.

The workshop began with an introduction (David Phizacklea) and a review of overall study and aims of the workshop (Terry Hume). This was followed by a review of results of catchment runoff studies (Sandy Elliott) and a review of results of estuary sedimentation studies (Mal Green). The presentations of Hume, Elliott and Green are reproduced in Appendix 1.

Prior to the workshop the participants had been provided with two key technical reports[1] [2] from the study. These describe the effects of changing landuse and climate over the next 50 years (from the present day 2001) on sediment runoff from the catchment to southern Tauranga Harbour and, in particular on: (1) the relative contributions of the various sediment sources in the subcatchments catchment surrounding southern Tauranga Harbour, (2) the characteristics of significant sediment sources, and (3) the fate (dispersal and deposition) of catchment sediments in the various subestuaries of southern Tauranga Harbour. The key results from these reports are summarised in Appendix 2. Discussion of these catchment and estuary modelling results at the workshop identified that the models produced information which was in accord with the general patterns expected by the workshop attendees.

[1] Elliott, A.; Parshotam, A. & Wadhwa, S. (2009). Tauranga Harbour Sediment Study, Catchment Model Results. NIWA Client Report HAM2009–046, prepared for Environment Bay of Plenty, April 2009. 40 p.

[2] Green, M.O. (2009). Tauranga Harbour Sediment Study: Predictions of harbour sedimentation under future scenarios. NIWA Client Report HAM2009–078, prepared for Environment Bay of Plenty, June 2009. 64 p

Once any issues raised by the attendees had been clarified, the workshop set about the assessment of predictions for management. It considered the southern harbour region at the subcatchment and subestuary scale, and then identified the issues and mitigations and actions considered possible in the context of the catchment runoff and estuary sedimentation findings predicted by the study. Results were recorded on a whiteboard.

The whiteboard exercise provided a high level analysis of issues and mitigation options for 19 of the subestuaries. It allowed potential sediment management interventions to be ranked. A more detailed analysis was attempted for the Rangataua Bay subestuary (and its contributing Waitao subcatchment).

Workshop proceedings

The information that emerged from the workshop is summarised in two tables that capture information from the white boards. Subsequent to the workshop some additional information from the study technical reports has been added to provide further clarification.

Table 6.1 provides a high level summary of subcatchment and subestuary factors which influence the choice of mitigation options to address the sedimentation issues in each subestuary. The rankings (1 low, though to 5 high) are an indication of the likely effectiveness that any mitigation action taken in the subcatchment will reduce the predicted sedimentation rate in the subestuary. The rankings are a function of subcatchment size and properties (such as landuse, soils, slope etc.) and how the values of the subestuary could be diminished if the predicted increased sedimentation rate occurs. The ranking provides a measure of the overall potential for success of identified mitigation procedures. The columns listing key subcatchment and subestuary factors indicate the data that must be considered in making the decisions. Intervention options are described in the right hand column.

An important point to emerge from the discussions was that in most cases the sediment issue is best dealt with at source, that is dealt with in the subcatchment before the sediment reaches the estuary. Mangrove management and dredging of sediment build-up are among the few intervention/mitigation options available once the sediment is deposited in the estuary.

Table 6.2 is the summary of a more detailed analysis of issues and management options for a single subestuary (in this case Rangataua Bay subestuary). The 'Doable' column provides a place to record whether action/mitigations are practical, taking into account factors such as cost, available resources to do the work, practicality of actions and whether more work is needed to assist with the decision making process.

Table 6.1: High level summary for the subcatchment and subestuary factors which determine the potential for mitigation options to address the sedimentation issues. The ranking (1 low, though to 5 high) are an indication of the likely effectiveness of any action taken. The question marks indicate knowledge gaps at the time of the workshop.

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Subestuary (number)	Corresponding subcatchment	Potential for mitigation success 1=low, 5=high	Key subcatchment factors influencing choice of mitigation/intervention options	Key subestuary factors influencing choice of mitigation/intervention options	Intervention options discussed in workshop
Speedway (1)	Papamoa	2	Size. Sed input. Steepness? Soil? Landuse? River flushing?	River flushing low (limited input). Low hydrodynamic activity especially at the fringes (mangroves). Sedimentation rate is predicted to be high.	
Rangataua Bay (2)	Waitao	5	Size. Sed input. Steepness? Soil? Landuse? River flushing?	River flushing effect? Hydrodynamically active. The high sedimentation rates of adjacent subestuaries (Welcome Bay and Speedway) will mean muddy sediment encroaches into this subestuary.	
Welcome Bay (3)	Kaitemako	5	45 km^2. Sed input. Steepness? Soil? Landuse? River flushing?	Protected. Low river flushing and weak hydrodynamics. Settling area especially around the fringes (mangroves). Sedimentation rate is predicted to be high.	
Waimapu (4)	Waimapu	5	Large catchment. Sed input? Steepness? Soil? Landuse?	Enclosed settling basin. Artificially enclosed by bridge which reduces hydrodynamic energy and river flushing capability. Low hydrodynamic activity. Sedimentation rates are predicted to increase.	Any mitigation should be in the catchment.
Waikareao (7)	Kopurererua	5	Medium size catchment. Sed input? Steepness? Soil? Landuse?	Enclosed settling basin, restricted by a bridge/causeway which reduces hydrodynamic energy and river flushing capability. Low hydrodynamic activity. Sedimentation rates are predicted to increase.	Action must be in the catchment.
Wairoa (8)	Wairoa	2	Very large catchment. Total runoff is large however 95% of all fine sediment is flushed to the sea. High sediment input. The principal sediment provider to 5 other subestuaries (6, 11, 18, 19, 25). Steepness? Soil? Landuse? River flushing is high.	High degree of river flushing and highly hydrodynamically active (waves and tides). 95% of all input fine sediment is flushed to the sea. No increase in sedimentation rate is predicted.	Would need large effort to control sediment for small return given that no increase is predicted in sedimentation rate.

Table 6.1: (cont.)

Subestuary (number)	Corresponding subcatchment	Potential for mitigation success 1=low, 5=high	Key subcatchment factors influencing choice of mitigation/intervention options	Key subestuary factors influencing choice of mitigation/intervention options	Intervention options discussed in workshop
Waikaraka (9)	Oturu	5	Very small catchment. Sed input? Steepness? Soil? Landuse? River flushing?	River flushing effect? The outer estuary is hydrodynamically active although it is partially protected by a spit. Increased sed. rates predicted and if the spit further encloses the mouth, sedimentation rates could be higher.	Small catchment where intervention is practical
Te Puna outer (10)	Te Puna	5	Small catchment. Sed input? Steepness? Soil? Landuse? River flushing?	The outer estuary is hydrodynamically active although it is partially protected by a spit. Low sedimentation rates predicted but if the spit further encloses the mouth sedimentation rates could increase.	Small catchment where intervention is practical
Mangawhai outer (11)	Mangawhai	2	Small catchment. Sed input? Steepness? Soil? Landuse? River flushing?	Principal sediment source is the distant Wairoa River. Exhibits a gradient of hydrodynamic activity having protected upper reaches and active outer area. Low sedimentation rate is predicted.	
Waipapa (12)	Waipapa	5	Small catchment. Sed input? Steepness? Soil? Landuse? River flushing?	River flushing effect? Waipapa is enclosed, protected from hydrodynamic activity. Increased sedimentation rate is predicted.	
Pahoia (13)	Apata	1	Very small catchment. (Check - Sed input? Steepness? Soil? Landuse? River flushing?)	River flushing effect? Embayment with protected headwaters and fringe (where dense established mangrove forests occur) and exposed mouths. Hydrodynamics? Increased sedimentation rate is predicted.	
Wainui (14)	Wainui	1	Small catchment. Sed input? Steepness? Soil? Landuse? River flushing?)	River flushing effect? Embayment with protected head and fringe (where dense established mangrove forests occur) and exposed mouths. Hydrodynamics? Sedimentation rates are already very high and not predicted to increase.	

Table 6.1: (cont.)

Subestuary (number)	Corresponding subcatchment	Potential for mitigation success 1=low, 5=high	Key subcatchment factors influencing choice of mitigation/intervention options	Key subestuary factors influencing choice of mitigation/intervention options	Intervention options discussed in workshop
Aongatete (15)	Aongatete	1	Large catchment. (Check - Sed input? Steepness? Soil? Landuse? River flushing?)	River flushing effect? Embayment with protected headwaters and fringe (where dense established mangrove forests occur) and exposed mouths. Sedimentation rates are predicted to increase.	
Matakana (17.18, 19)	Matakana 1 & 2	1	Small flat catchments. Sed input? Steepness? Soil? Landuse? River flushing?	River flushing? Hydrodynamics? Most sediment for subestuaries 18 and 19 comes from the Wairoa. Small sedimentation rate is predicted.	
Mangawhai inner (20)	Mangawhai	2	Small catchment. Sed input? Steepness? Soil? Landuse? River flushing?	Enclosed by a railway causeway, low degree of tidal/river flushing and wave activity, making this a sediment trap. Probably trapping sediment from reaching the outer harbour, and could be regarded as sacrificial.	Small catchment where intervention is practical
Omokoroa (23)	no direct catchment	5	Nil	No major freshwater input so river flushing is negligible. Open and hydrodynamically active. Sedimentation rate is not predicted to increase although sediment from neighbouring Waipapa may encroach.	
Matua (25)	Bellevue	3	Small catchment. Sed input? Steepness? Soil? Landuse? River flushing?	Principal sediment source is Wairoa River. Some river flushing also provided by Wairoa River to the outer estuary. Hydrodynamically active except at the fringes and protected northern edge. Increased sedimentation rates predicted.	Few practical options other than mangrove removal. Need to check for potential controls on storm water outlets and construction of settling ponds?
Te Puna inner (26)	Te Puna	5	Small catchments. Sed input? Steepness? Soil? Landuse? River flushing?	Enclosed by a railway causeway, low degree of tidal/river flushing and wave activity, making this a sediment trap. Probably trapping of sediment preventing it from reaching the outer harbour, and could be regarded as sacrificial.	Small catchment where intervention is practical

Table 6.2: More detailed analysis of issues and management options for a single subestuary - Rangataua Bay subestuary #2 (Waitao subcatchment).

Rangataua Bay physical setting: 43 km^2 catchment with steep upper catchment. Sediment yield from Waitao subcatchment is high (>3 t/ha/yr). Normal soils? Comprises 3 subestuaries. Subestuary 2 (central area of Rangataua Bay) is well flushed and sediment will be transported away. The north (subestuary 1; Speedway) and south (subestuary 3; Welcome Bay) ends of Rangatawa Bay are sheltered and act as sediment traps. Bridge/causeway from the Mount to Maungatapu restricts flushing and wave action to some degree.

Subcatchment and subestuary issues/factors to consider	**Action/ mitigation**		**Are actions doable ?**	**Uncertainty**	**Further work?**
	Subcatchment	**Subestuary**			
Sediment runoff from catchment increases sedimentation rate in estuary Estuary is a sediment trap Mangroves take advantage of suitable habitat created by additional fine sediment in sheltered estuary fringes			☑	Exact contribution from the various sources in the subcatchment is unknown?	Quantify contribution of different sources? Cost effectiveness versus risk of sediment runoff associated with various combinations of landuse type What is an acceptable runoff loss? What are best practice options?
Pasture areas	Deal with issues at source Tighten controls or make different controls on subdivision /lifestyle blocks Riparian /pasture /erosion hotspots planting Construct large scale settling ponds	Need to work backwards from estuary to develop catchment Best Management Practice	☑	Mechanism for controlling intensity of farming Ultimate effect on suspended solids uncertain Bank erosion contribution unknown?	What is an acceptable runoff loss? What are best practice options? Determine bank erosion contribution to sediment runoff? Sediment settling pond design

Table 6.2: (cont.)

Subcatchment and subestuary issues/factors to consider	Action/ mitigation		Are actions doable ?	Uncertainty	Further work?
	Subcatchment	**Subestuary**			
Quarry activity	Deal with issues at source, prevent sediment runoff from quarry		☑		
Exotic forestry	Tighten or make different appropriate controls on forestry		☑	Timing of harvesting phase	What is an acceptable runoff loss? What are best practice options? Is landuse in upper catchment appropriate?
	Better NEW guidelines (self managed by industry/forestry)	Mangrove removal	☒	Physically difficult, Maybe just target fringe/foothold areas Only small hapu community to undertake remedial work	
		Dredging	☒	Dredging too costly and messy	

Presentations from the Workshop

Presentations from the Workshop include: 1) Review of the study and aims of the workshop, 2) Catchment modelling, and 3) Harbour sedimentation modelling.

Tauranga Harbour Sediment Study:
Assessment of predictions for management workshop
EBOP 13 July 2009

Review of study and aims of workshop

- Workshop aims
- Project aims
- Study approach
- Key findings catchment and estuary
- Points of clarification

- Predictions for management

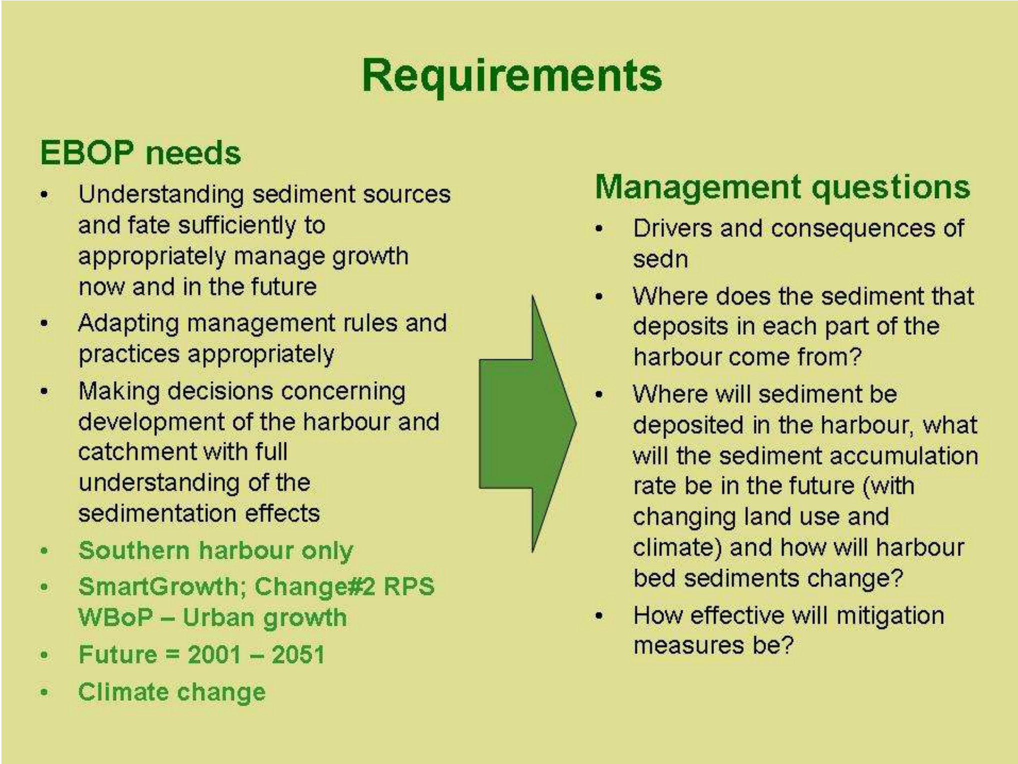
Terry Hume

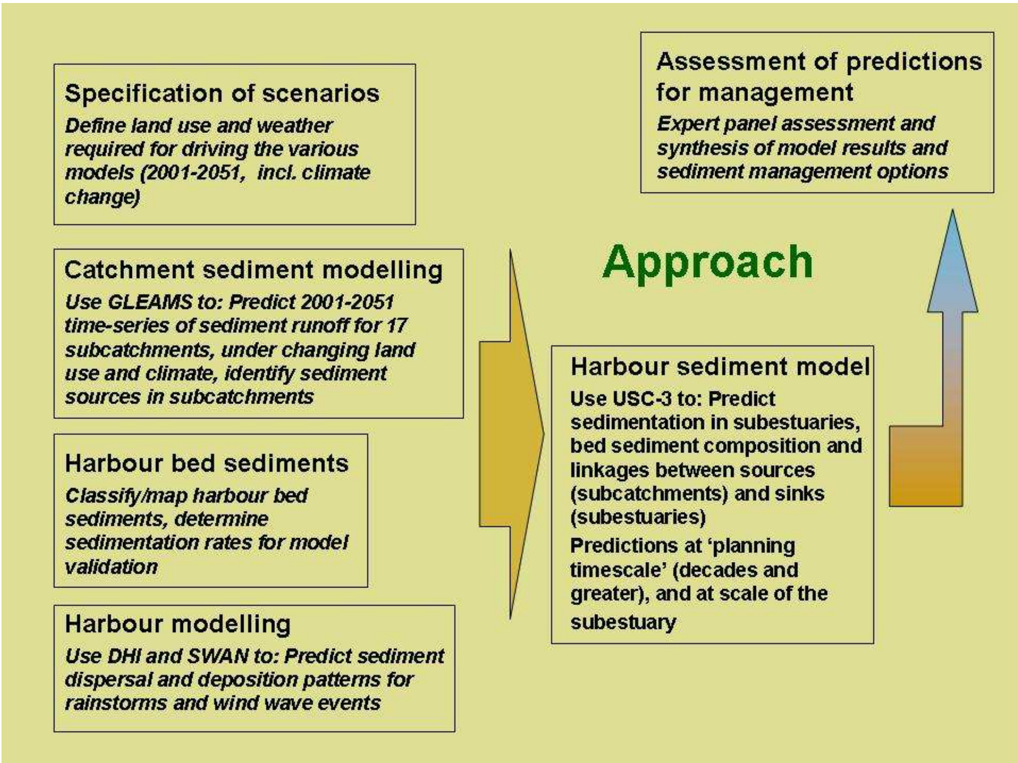
NIWA
Taihoro Nukurangi

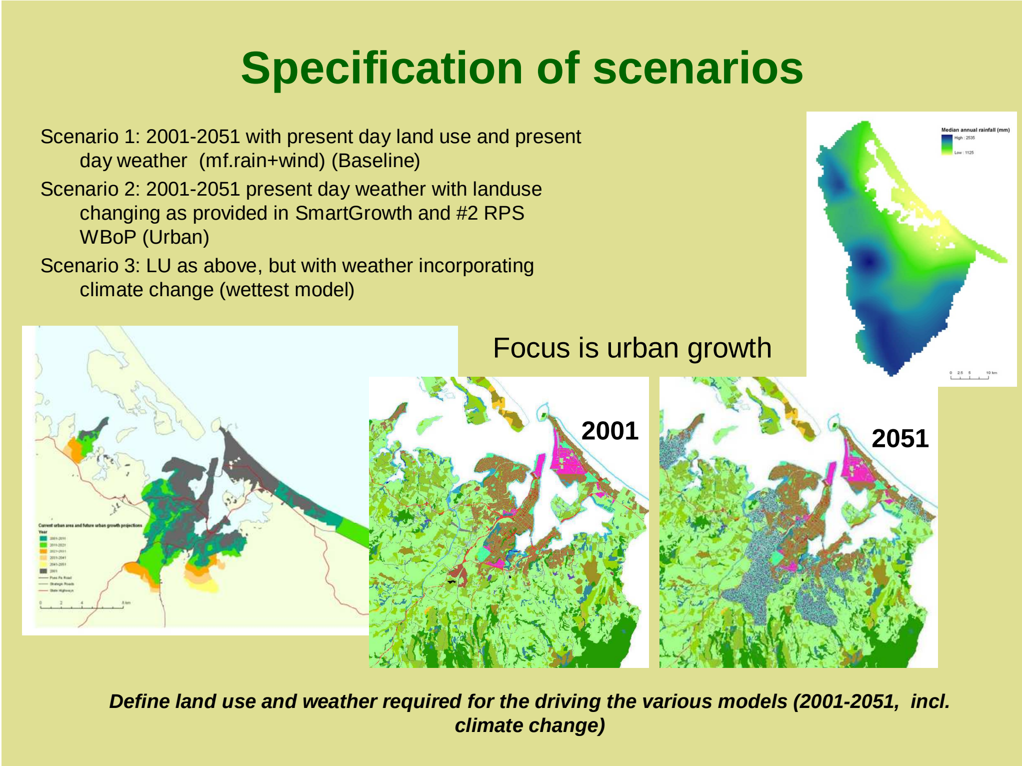
Assessment of predictions for management workshop

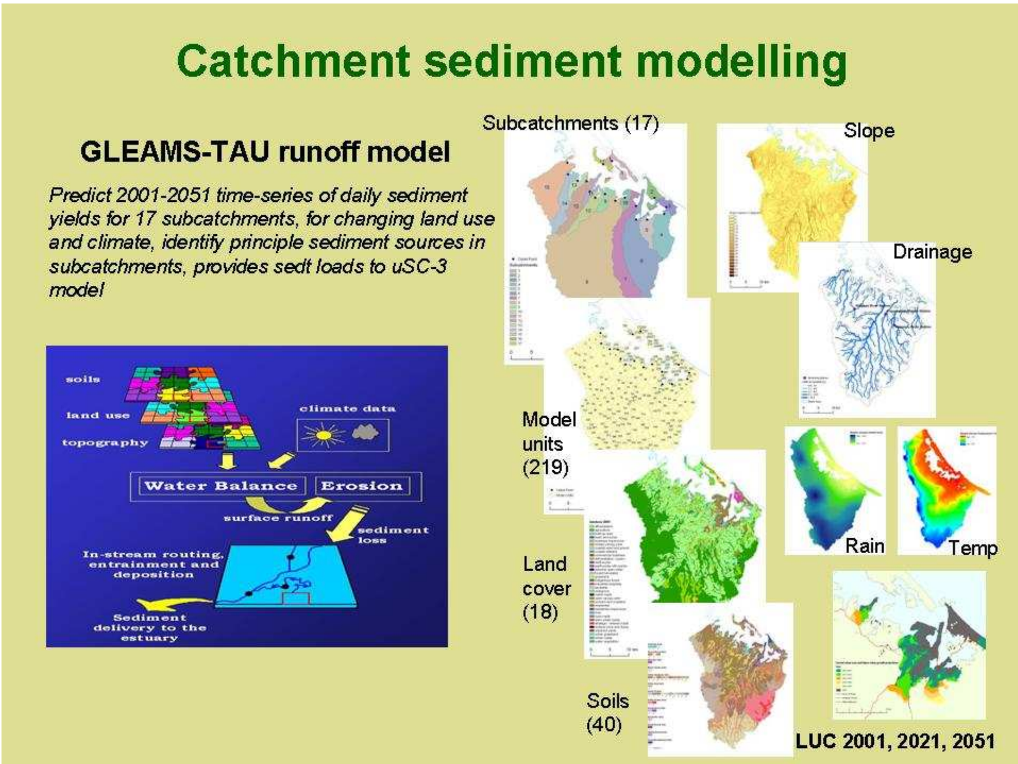
Expert panel assessment and synthesis of model results and sediment management options

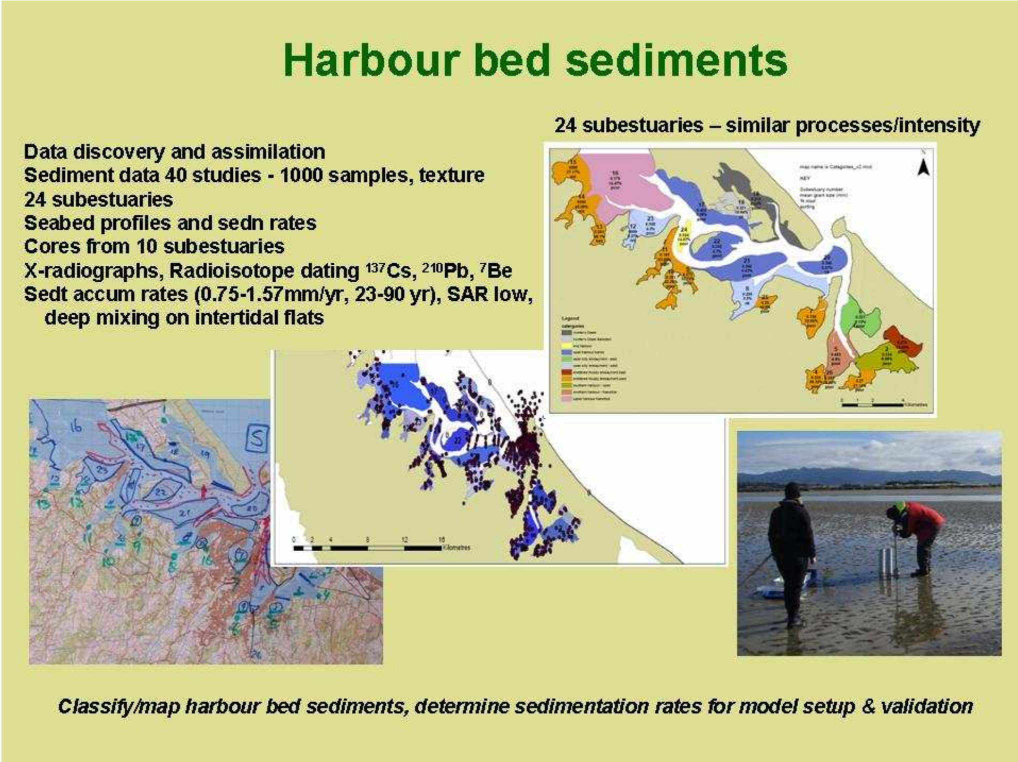
- **Catchment Priority Areas** - Which catchments are more important as priority areas for focusing resources to reduce sedimentation in the harbour?
- **Urban Development** - What are the likely effects of existing and future urban development on the harbour taking into account effects of climate change and a range of management practices?
- **Other Management** - How can the appropriate regulatory agencies (EBOP, WBPDC and TCC) most effectively address sedimentation issues, and what management intervention could be appropriate?
- **Reversal Methods** - Are there any reversal methods, such as mangrove control and channel dredging that may be effective?

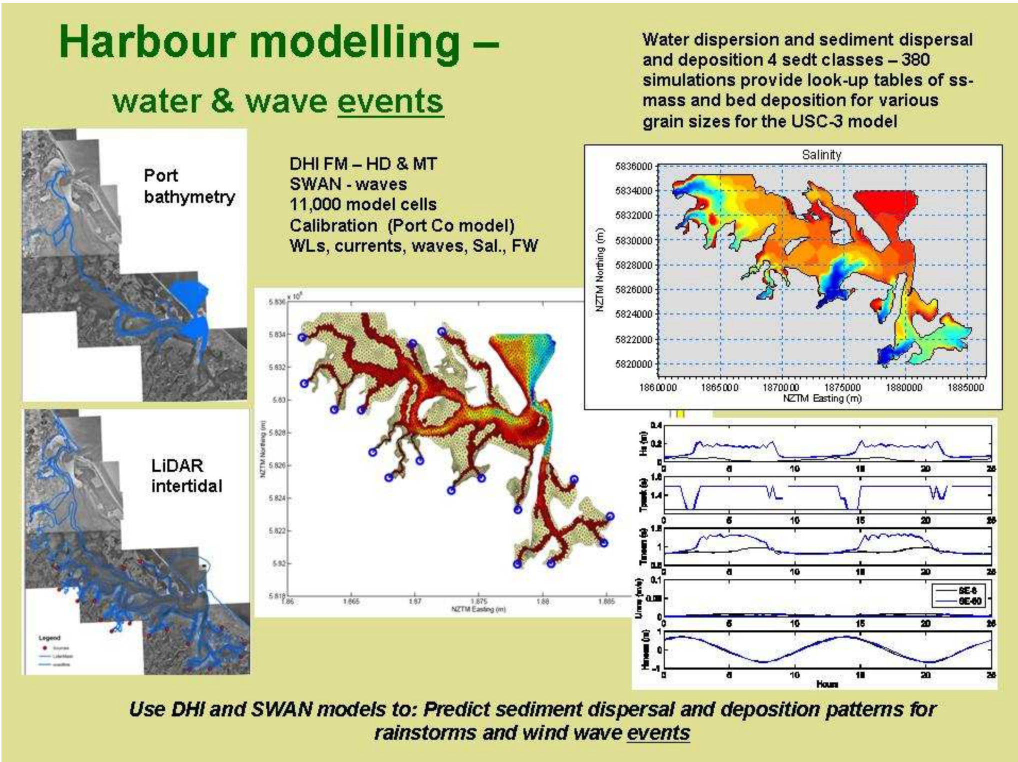

Requirements
EBOP needs
• Understanding sediment sources and fate sufficiently to appropriately manage growth now and in the future
• Adapting management rules and practices appropriately
• Making decisions concerning development of the harbour and catchment with full understanding of the sedimentation effects
• Southern harbour only
• SmartGrowth; Change#2 RPS WBoP – Urban growth
• Future = 2001 – 2051
• Climate change
Management questions
• Drivers and consequences of sedn
• Where does the sediment that deposits in each part of the harbour come from?
• Where will sediment be deposited in the harbour, what will the sediment accumulation rate be in the future (with changing land use and climate) and how will harbour bed sediments change?
• How effective will mitigation measures be?


Specification of scenarios
Define land use and weather required for driving the various models (2001-2051, incl. climate change)
Catchment sediment modelling
Use GLEAMS to: Predict 2001-2051 time-series of sediment runoff for 17 subcatchments, under changing land use and climate, identify sediment sources in subcatchments
Harbour bed sediments
Classify/map harbour bed sediments, determine sedimentation rates for model validation
Harbour modelling
Use DHI and SWAN to: Predict sediment dispersal and deposition patterns for rainstorms and wind wave events
Approach
Harbour sediment model
Use USC-3 to: Predict sedimentation in subestuaries, bed sediment composition and linkages between sources (subcatchments) and sinks (subestuaries)
Predictions at 'planning timescale' (decades and greater), and at scale of the subestuary
Assessment of predictions for management
Expert panel assessment and synthesis of model results and sediment management options


Specification of scenarios
Scenario 1: 2001-2051 with present day land use and present day weather (mf.rain+wind) (Baseline)
Scenario 2: 2001-2051 present day weather with landuse changing as provided in SmartGrowth and #2 RPS WBoP (Urban)
Scenario 3: LU as above, but with weather incorporating climate change (wettest model)
Focus is urban growth
2001
2051
Define land use and weather required for the driving the various models (2001-2051, incl. climate change)


Catchment sediment modelling
GLEAMS-TAU runoff model
Predict 2001-2051 time-series of daily sediment yields for 17 subcatchments, for changing land use and climate, identify principle sediment sources in subcatchments, provides sedt loads to uSC-3 model
soils
land use
topography
climate data
Water Balance
Erosion
surface runoff
sediment loss
In-stream routing, entrainment and deposition
Sediment delivery to the estuary
Subcatchments (17)
Slope
Drainage
Model units (219)
Rain
Temp
Land cover (18)
Soils (40)
LUC 2001, 2021, 2051


Harbour bed sediments
24 subestuaries – similar processes/intensity
Data discovery and assimilation
Sediment data 40 studies - 1000 samples, texture
24 subestuaries
Seabed profiles and sedn rates
Cores from 10 subestuaries
X-radiographs, Radioisotope dating ¹³⁷Cs, ²¹⁰Pb, ⁷Be
Sedt accum rates (0.75-1.57mm/yr, 23-90 yr), SAR low, deep mixing on intertidal flats
Classify/map harbour bed sediments, determine sedimentation rates for model setup & validation


Harbour modelling –
water & wave events
Water dispersion and sediment dispersal and deposition 4 sedt classes – 380 simulations provide look-up tables of ss-mass and bed deposition for various grain sizes for the USC-3 model
Port bathymetry
DHI FM – HD & MT
SWAN - waves
11,000 model cells
Calibration (Port Co model)
WLs, currents, waves, Sal., FW
Salinity
NZTM Northing (m)
NZTM Easting (m)
LiDAR intertidal
Hours
Use DHI and SWAN models to: Predict sediment dispersal and deposition patterns for rainstorms and wind wave events

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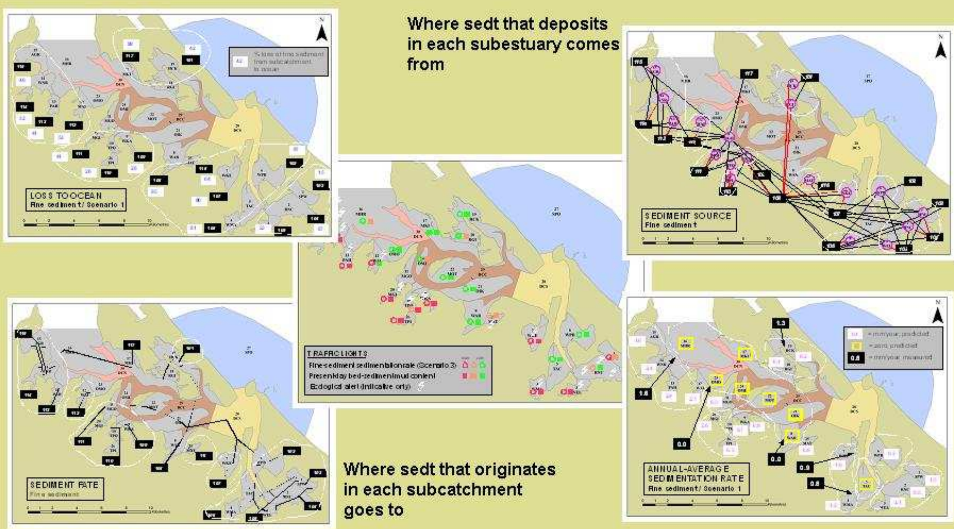
Taihoro Nukurangi

USC-3 sediment model



Use USC-3 to: Predict sedimentation in subestuaries, bed sediment composition and linkages between sources (subcatchments) and sinks (subestuaries) – subestuary space scales & decadal time scales

Key findings

Non objective specific outputs

- Data base verification and compilation
- Synergy with the Port Company modelling
- Models setup for further work
- Template for study of northern harbour
- ID of areas for priority monitoring

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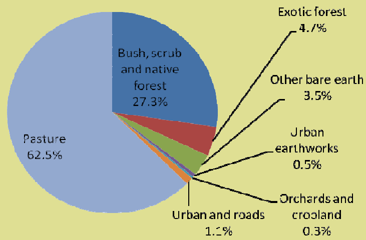
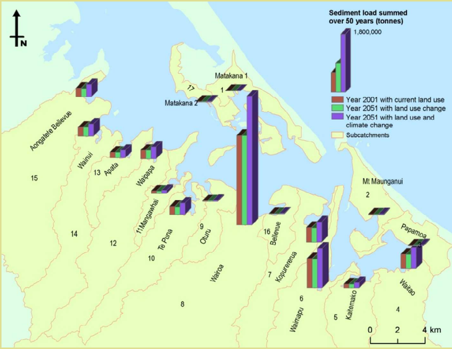
Key findings





- The largest subcatchment (Wairoa) produces most sediment
- Most sediment (63%) is from pastoral land use
- Contribution from cropland and pines relatively small
- Earthworks contribution small (<0.5%)
- Urbanisation will results in a small decrease in sediment loads (down 0.75%)
- Climate change predicted to increase sediment loads substantially (42.8%)

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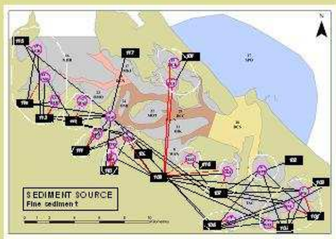
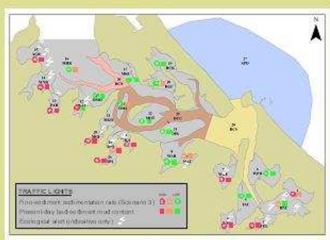
Key findings





USC-3 predicted effects are at scale of subestuary and at timescales of decades

- Substantial fine sediment loss to the ocean from those subestuaries close to entrance (Wairoa 95%)
- No exact correspondence between change in sed rate in a given subestuary and runoff from its contributing subcatchment
- Increases in sedn rate in subestuaries are greater than increases in runoff from the primary contributing subcatchment
- Climate change is a dominant driver of sedn in estuaries

Use USC-3 to: Predict sedimentation in subestuaries, bed sediment composition and linkages between sources (subcatchments) and sinks (subestuaries)

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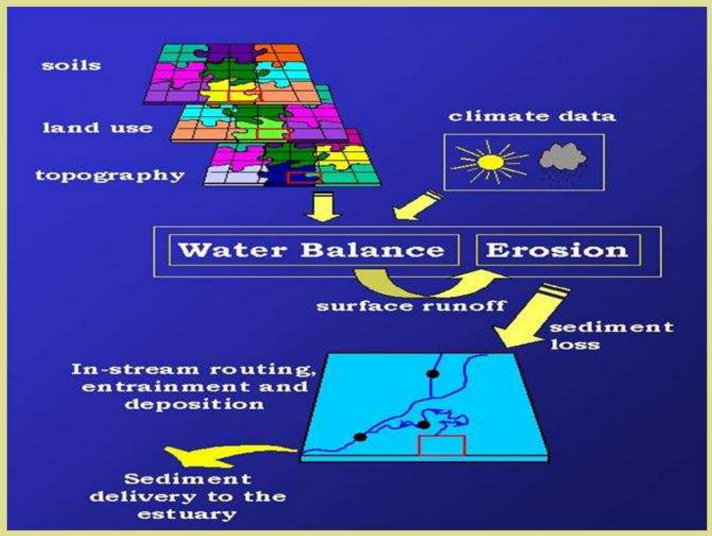
Tauranga Harbour Sediment Study:
Assessment of predictions for management workshop
EBOP 13 July 2009

Catchment modelling

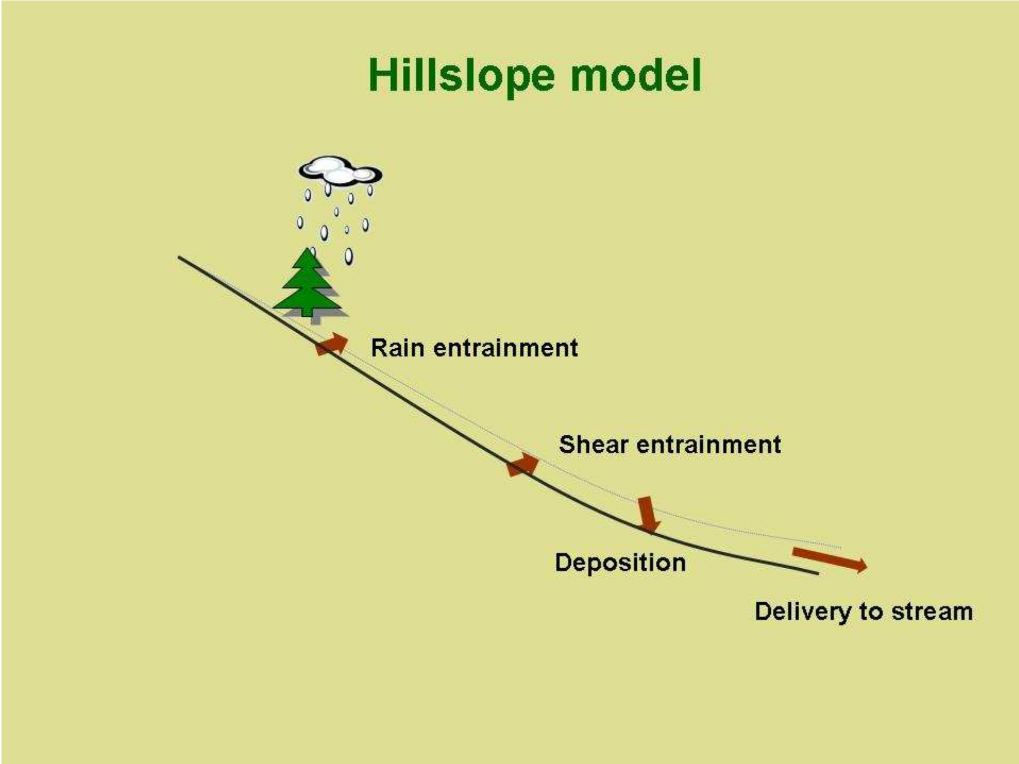
- How the model works
- Input data
- Validation
- Results

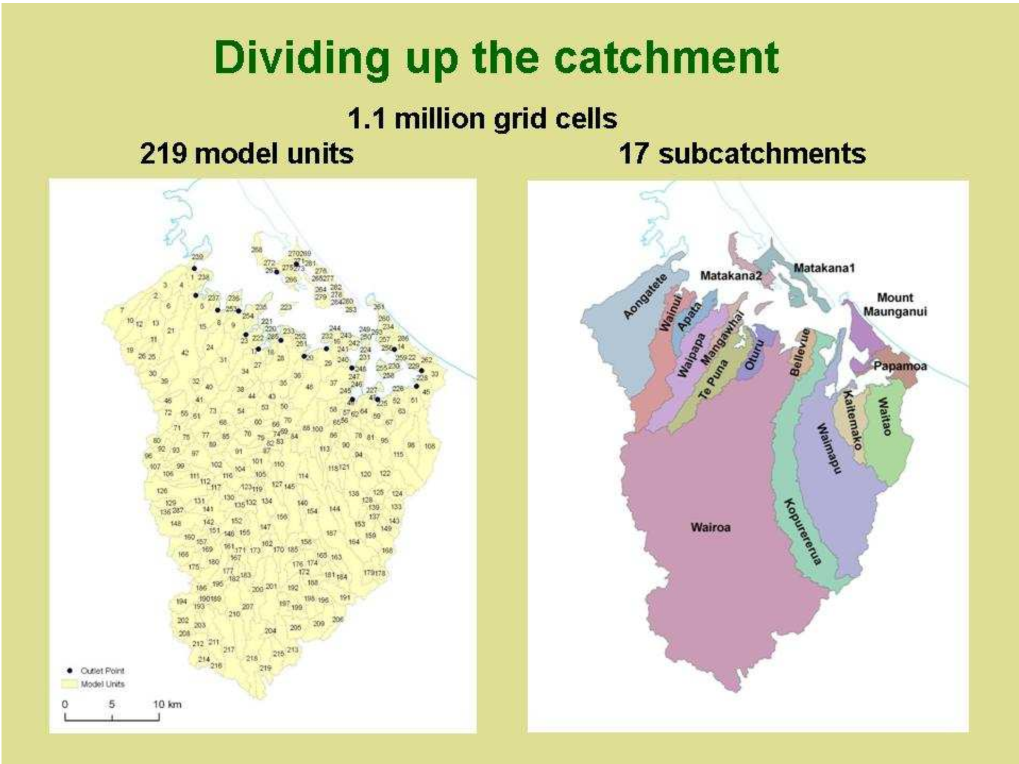
Sandy Elliott
Aroon Parshotam
Sanjay Wadhwa
Brett Mullan
NIWA
Taihoro Nukurangi

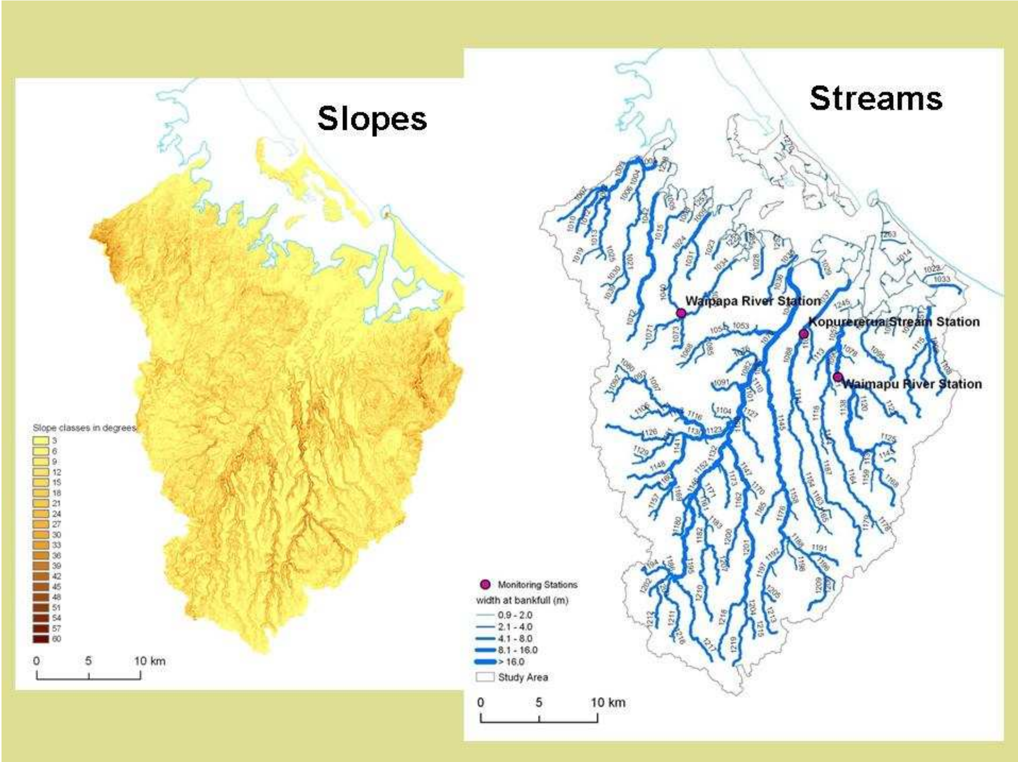
GLEAMS-Tau catchment model

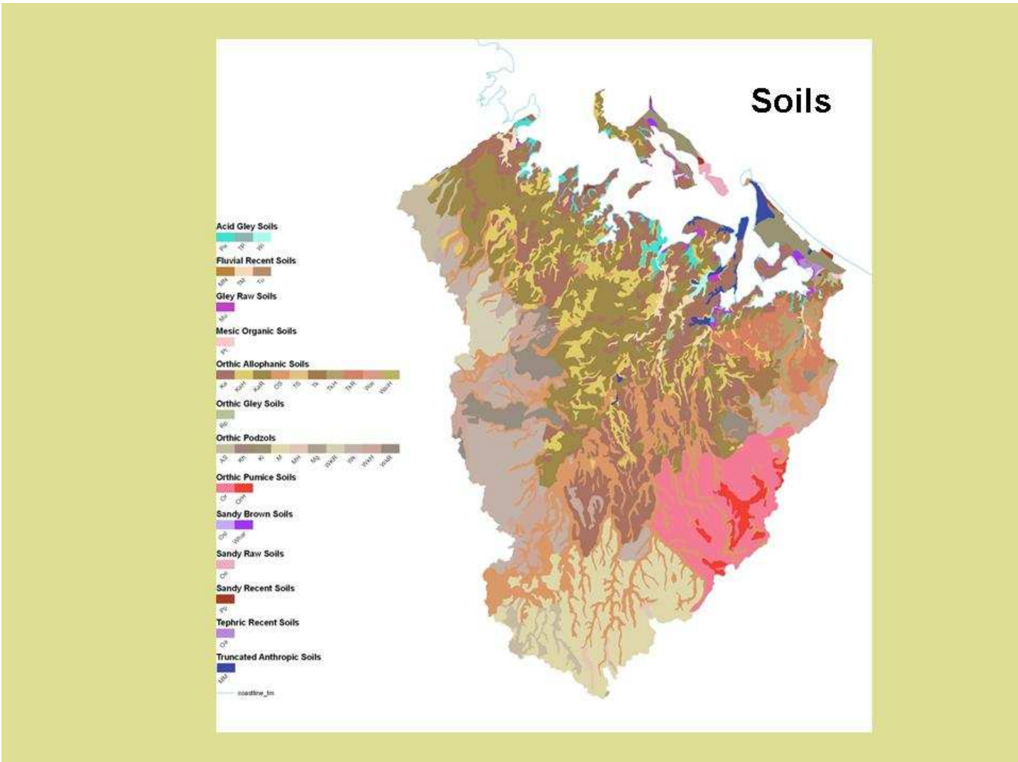


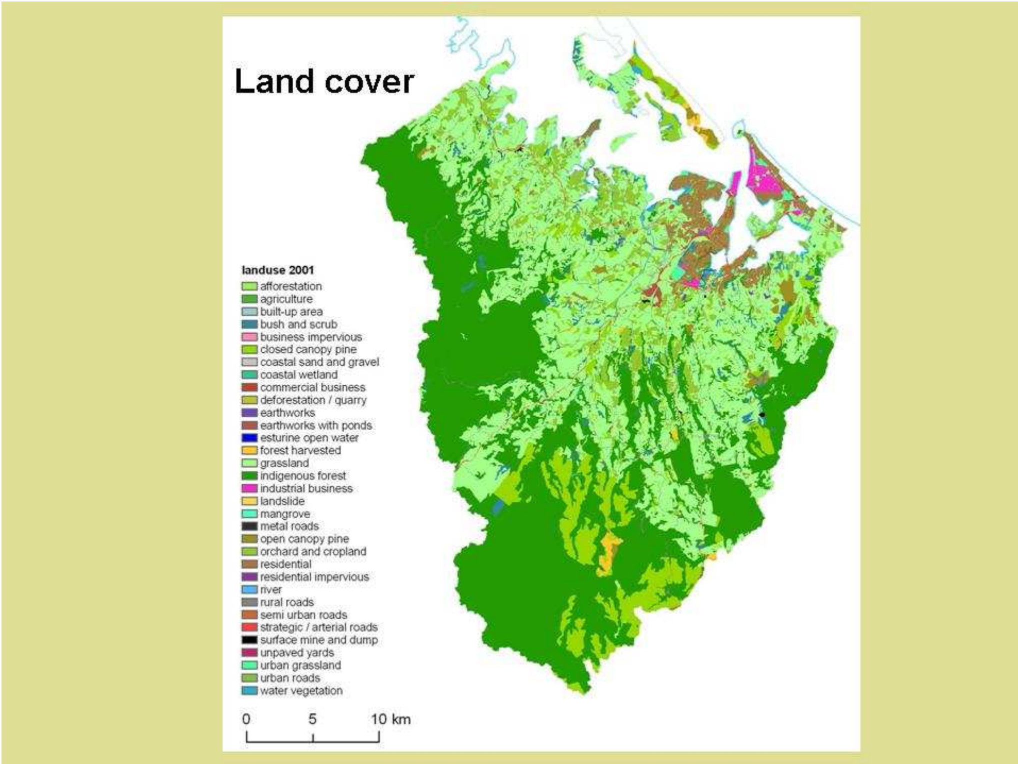
30 m x 30 m grid cells. Catchment of 994 km². 1.1 million cells

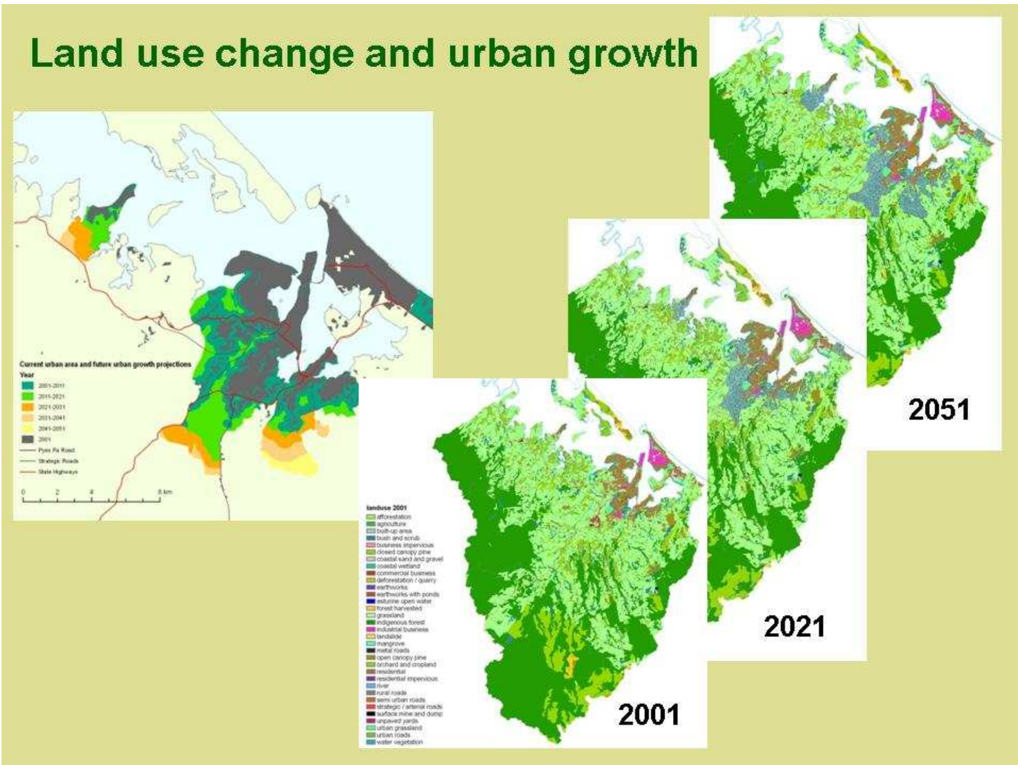

Hillslope model
Rain entrainment
Shear entrainment
Deposition
Delivery to stream

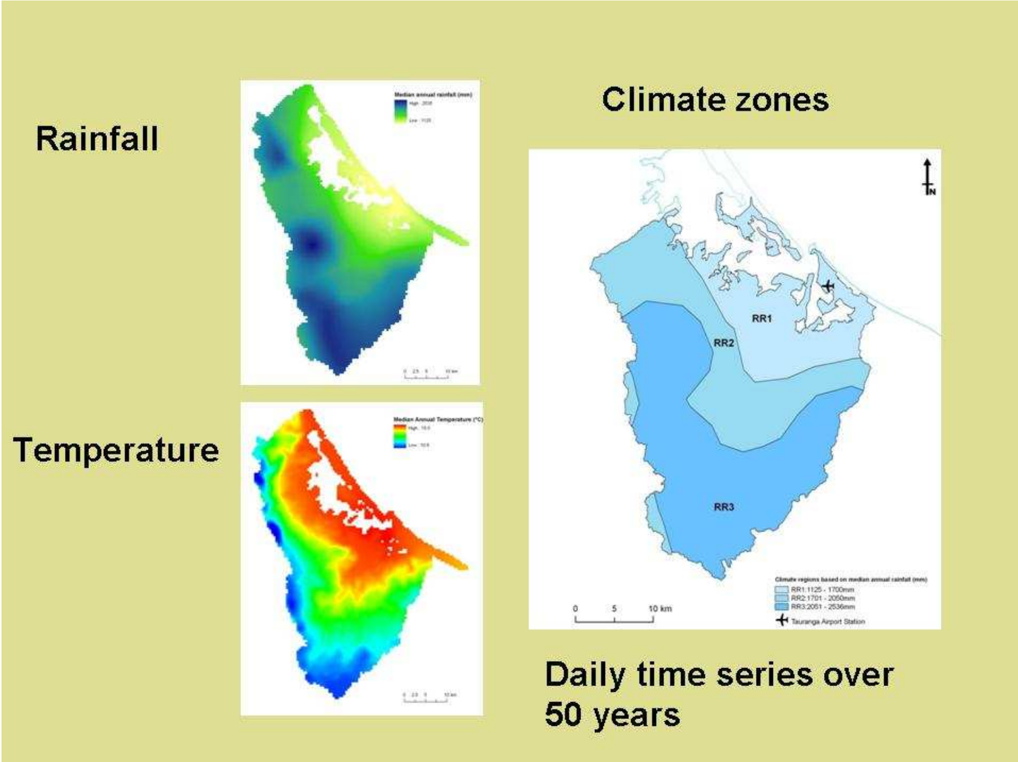

Dividing up the catchment
1.1 million grid cells
219 model units
17 subcatchments
Outlet Point
Model Units
0 5 10 km
Aongatete
Matakana2
Matakana1
Mount Maunganui
Wainui
Apata
Waipapa
Mangawhai
Te Puna
Oturu
Bellevue
Papamoa
Kaitemako
Waitao
Waimapu
Kopurererua
Wairoa

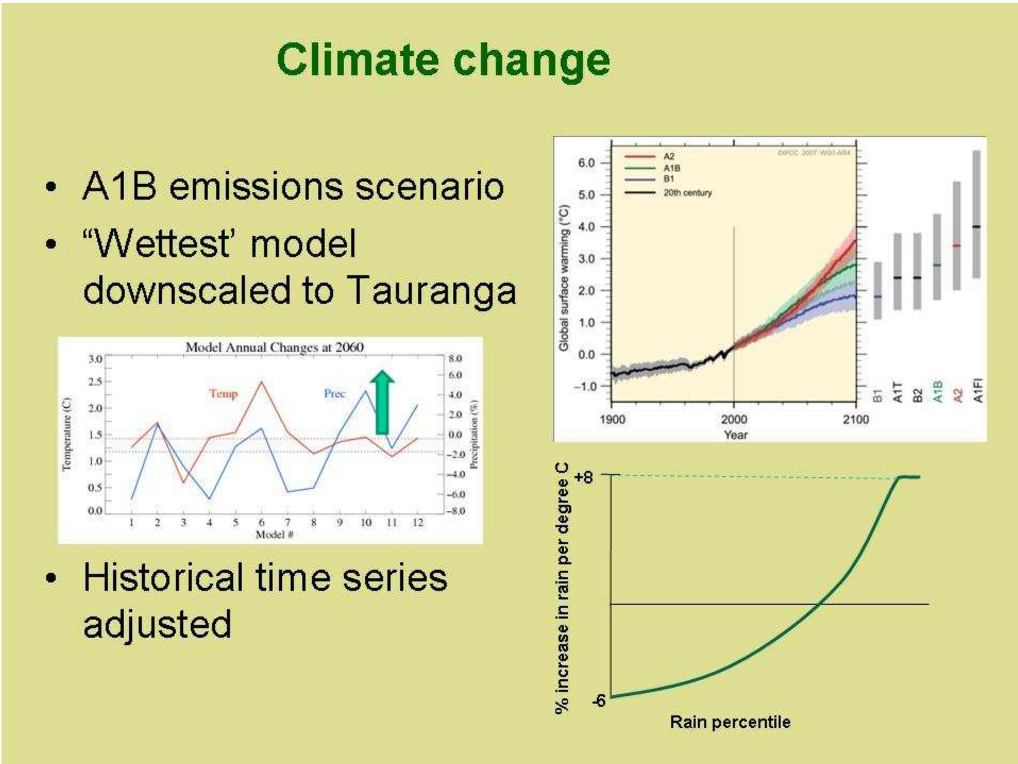

Slopes
Slope classes in degrees
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
54
57
60
0 5 10 km
Streams
Waipapa River Station
Kopurererua Stream Station
Waimapu River Station
Monitoring Stations
width at bankfull (m)
0.9 - 2.0
2.1 - 4.0
4.1 - 8.0
8.1 - 16.0
> 16.0
Study Area
0 5 10 km

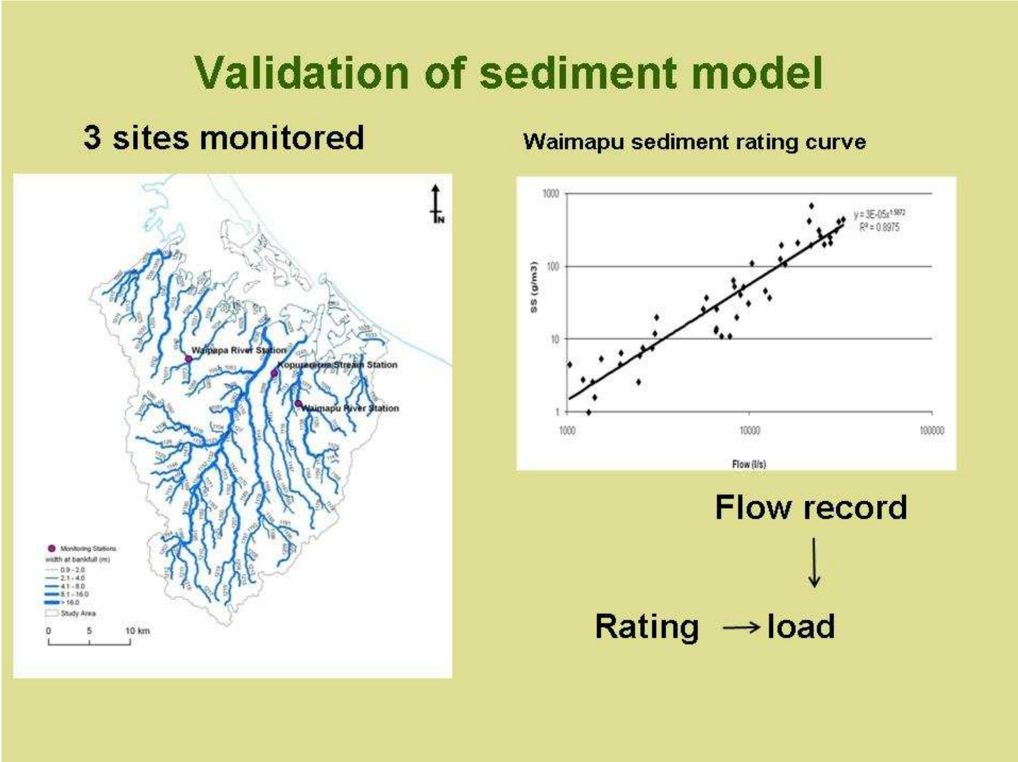

Soils
Acid Gley Soils
Fluvial Recent Soils
Gley Raw Soils
Mesic Organic Soils
Orthic Allophanic Soils
Orthic Gley Soils
Orthic Podzols
Orthic Pumice Soils
Sandy Brown Soils
Sandy Raw Soils
Sandy Recent Soils
Tephric Recent Soils
Truncated Anthropic Soils
coastline_tm

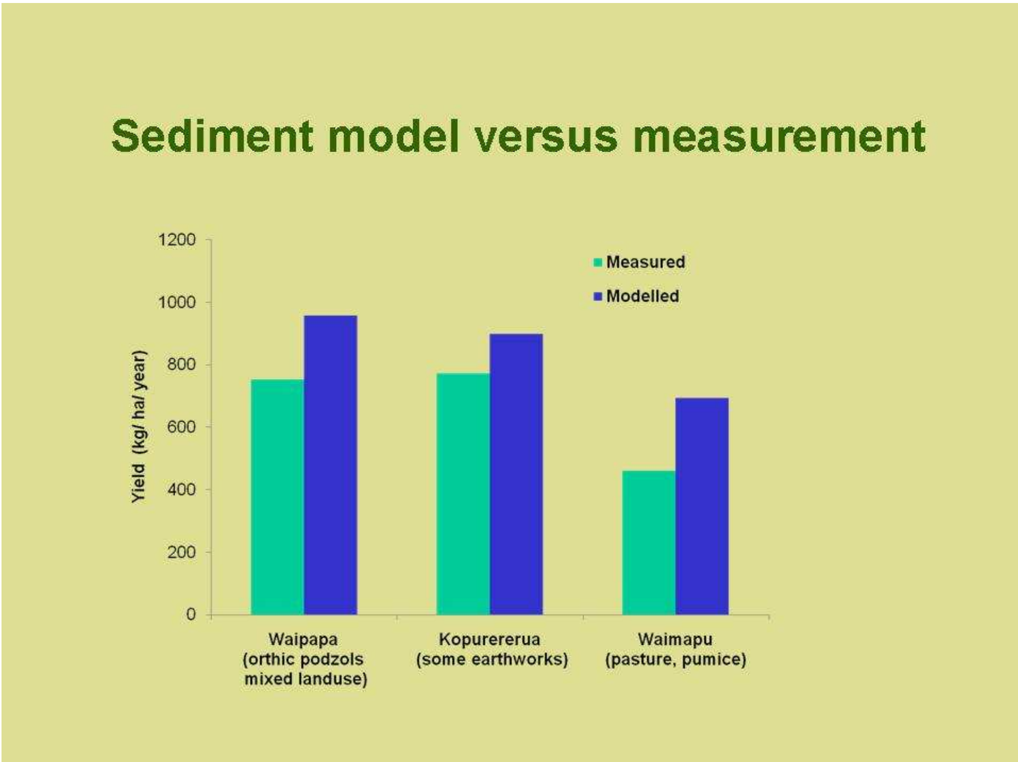

Land cover
landuse 2001
afforestation
agriculture
built-up area
bush and scrub
business impervious
closed canopy pine
coastal sand and gravel
coastal wetland
commercial business
deforestation / quarry
earthworks
earthworks with ponds
esturine open water
forest harvested
grassland
indigenous forest
industrial business
landslide
mangrove
metal roads
open canopy pine
orchard and cropland
residential
residential impervious
river
rural roads
semi urban roads
strategic / arterial roads
surface mine and dump
unpaved yards
urban grassland
urban roads
water vegetation
0
5
10 km


Land use change and urban growth
2051
2021
2001


Rainfall
Temperature
Climate zones
RR1
RR2
RR3
Daily time series over 50 years


Climate change
• A1B emissions scenario
• "Wettest' model downscaled to Tauranga
Model Annual Changes at 2060
Temp
Prec
Temperature (C)
Precipitation (%)
Model #
• Historical time series adjusted
A2
A1B
B1
20th century
Global surface warming (°C)
Year
B1
A1T
B2
A1B
A2
A1FI
% increase in rain per degree C
+8
-6
Rain percentile

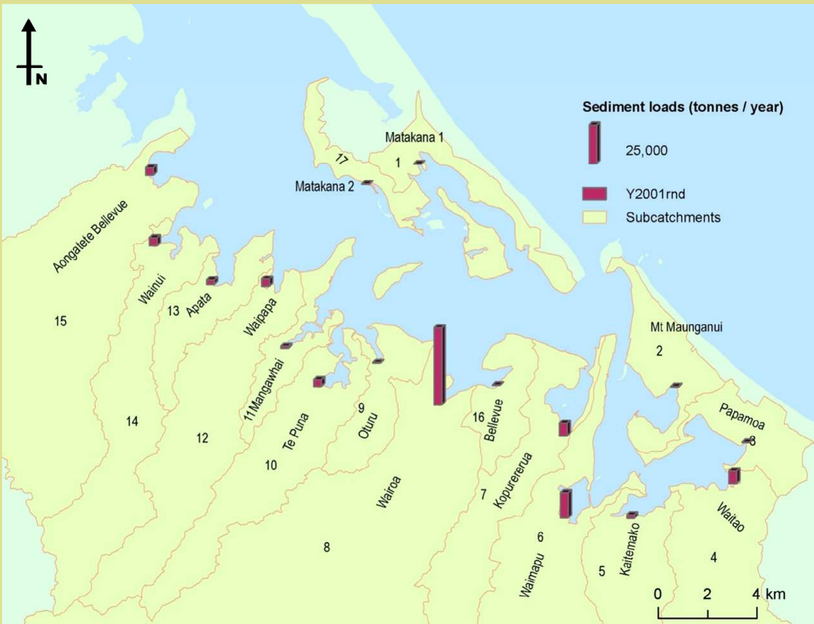

Validation of sediment model
3 sites monitored
Waipapa River Station
Kopurererua Stream Station
Waimapu River Station
0 5 10 km
Waimapu sediment rating curve
1000
100
10
1
SS (g/m3)
1000
10000
100000
Flow (l/s)
Flow record
Rating → load


Sediment model versus measurement
1200
1000
800
600
400
200
0
Yield (kg/ ha/ year)
Measured
Modelled
Waipapa (orthic podzols mixed landuse)
Kopurererua (some earthworks)
Waimapu (pasture, pumice)

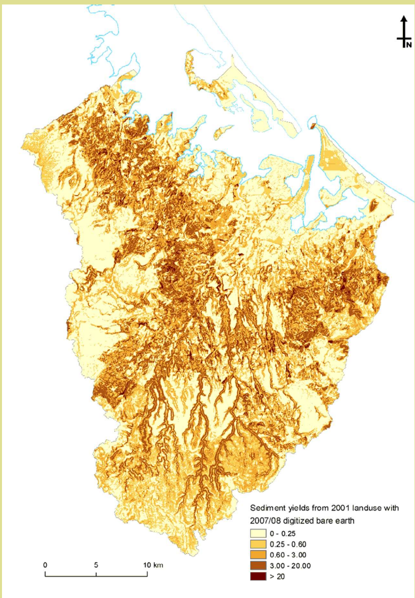
Key questions

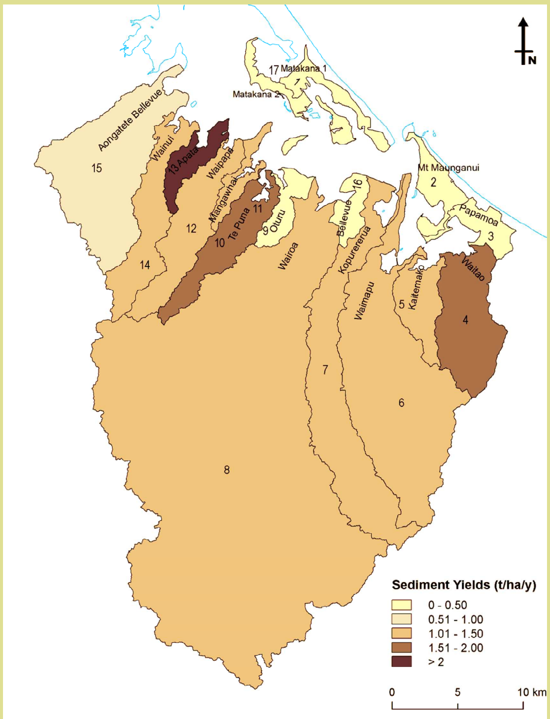
- Where is most sediment generated?
- What affects the amount of sediment
- What is the effect of future urbanisation?
- What is the effect of climate change?

Sediment loads by subcatchment



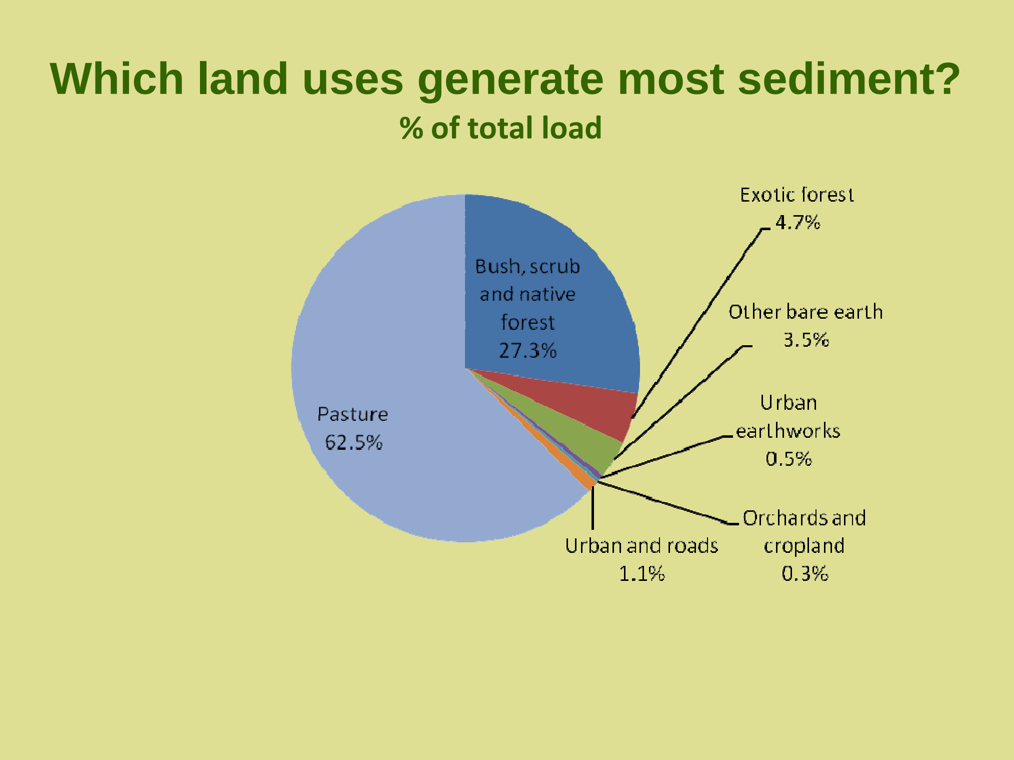
Source of sediment

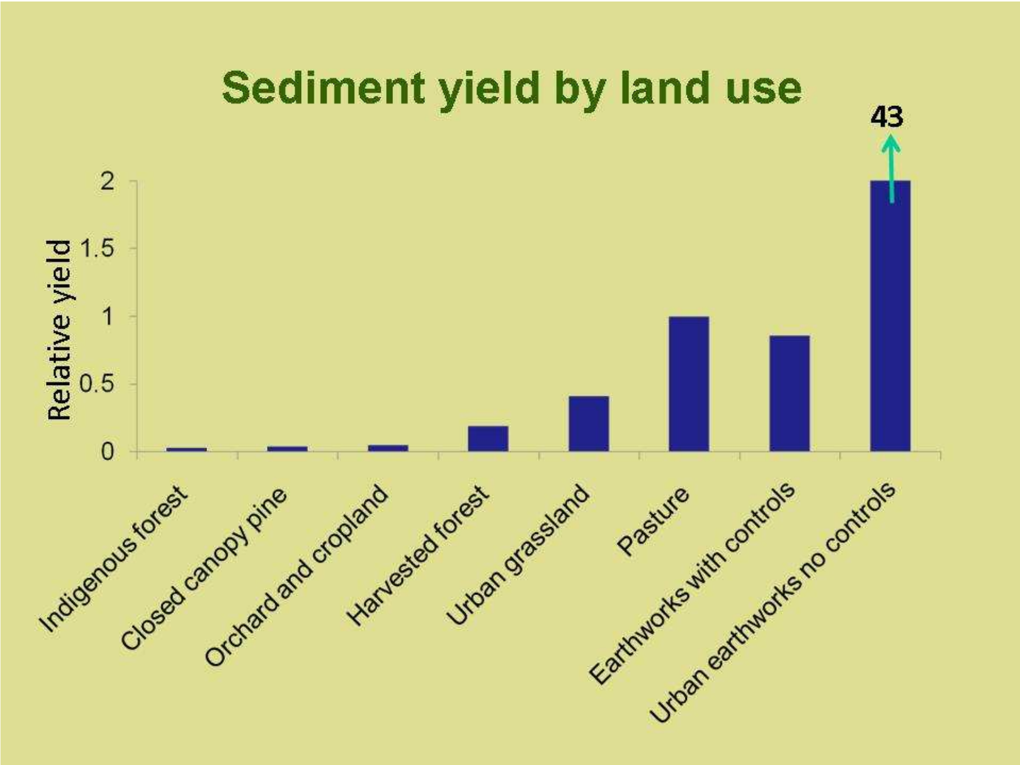




Key questions

- Where is most sediment generated?
- What affects the amount of sediment?
- What is the effect of future urbanisation?
- What is the effect of climate change?


Which land uses generate most sediment?
% of total load
Bush, scrub and native forest 27.3%
Pasture 62.5%
Exotic forest 4.7%
Other bare earth 3.5%
Urban earthworks 0.5%
Orchards and cropland 0.3%
Urban and roads 1.1%


Sediment yield by land use
43
Relative yield
2
1.5
1
0.5
0
Indigenous forest
Closed canopy pine
Orchard and cropland
Harvested forest
Urban grassland
Pasture
Earthworks with controls
Urban earthworks no controls

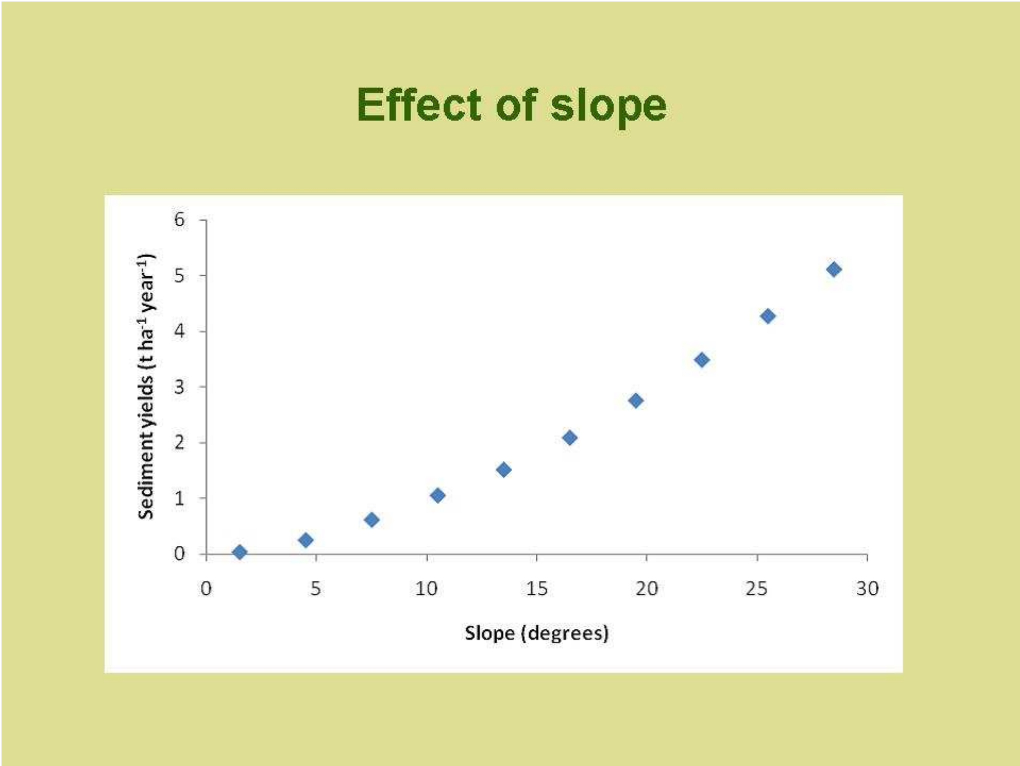
Sediment yield by soil type

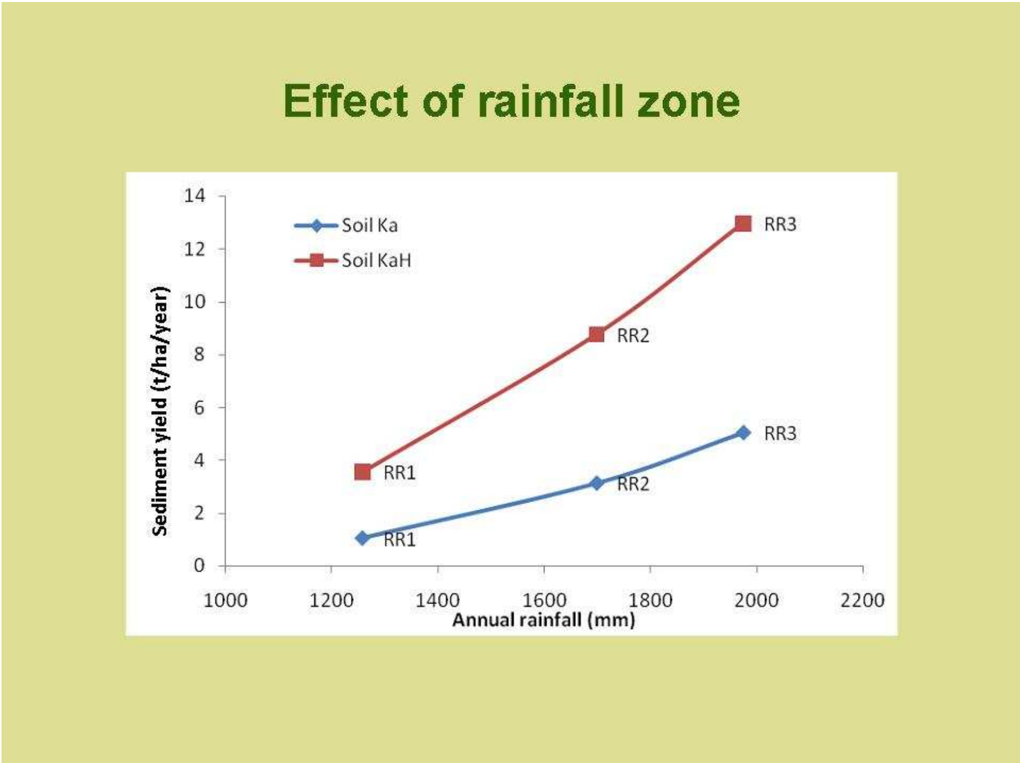
NZ Soil Order	Sediment yield† ($t\ ha^{-1}\ year^{-1}$)	Area of soil in the catchment (%)
Acid Gley Soils	10.21	1.39
Fluvial Recent Soils	3.33	1.02
Gley Raw Soils	5.48	0.57
Mesic Organic Soils	6.34	0.03
Orthic Allophanic Soils	1.95	56.2
Orthic Gley Soils	3.09	0.13
Orthic Podzols	2.02	30.11
Pumice Soils	0.87	7.68
Sandy Brown Soils	4.70	0.1
Sandy Raw Soils	1.18	0.29
Sandy Recent Soils	0.50	0.12
Tephric Recent Soils	1.02	0.12
Truncated Anthropic Soils	1.34	0.82

†Assuming pasture with 10.5 degree slope and rainfall region, RR1

Sediment load by soil type

NZ Soil Order	Contribution (%)
Acid Gley Soils	1.19
Fluvial Recent Soils	0.43
Gley Raw Soils	0.03
Mesic Organic Soils	<0.01
Orthic Allophanic Soils	80.27
Orthic Gley Soils	0.02
Orthic Podzols	12.91
Pumice Soils	4.94
Sandy Brown Soils	0.01
Sandy Raw Soils	<0.01
Sandy Recent Soils	<0.01
Tephric Recent Soils	<0.01
Truncated Anthropic Soils	0.17

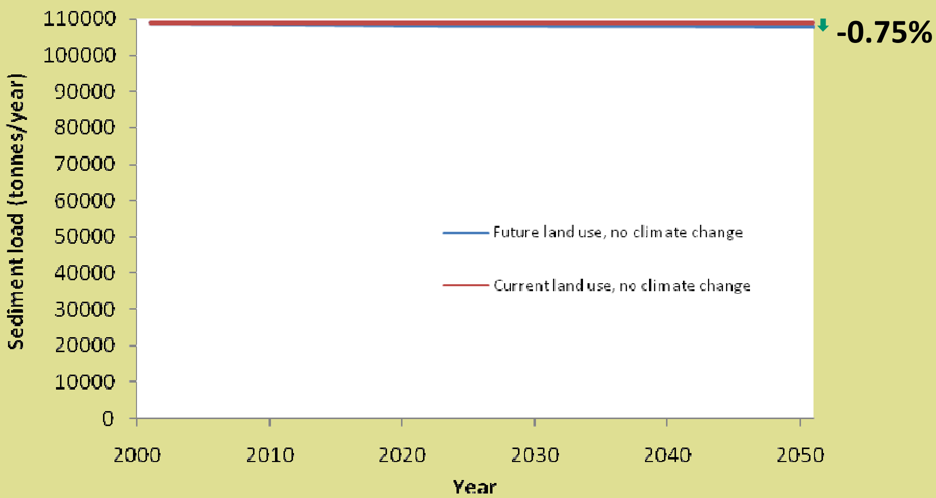

Effect of slope
Sediment yields (t ha-1 year-1)
Slope (degrees)
0
1
2
3
4
5
6
0
5
10
15
20
25
30


Effect of rainfall zone
Soil Ka
Soil KaH
RR1
RR2
RR3
RR1
RR2
RR3
Sediment yield (t/ha/year)
Annual rainfall (mm)
0
2
4
6
8
10
12
14
1000
1200
1400
1600
1800
2000
2200

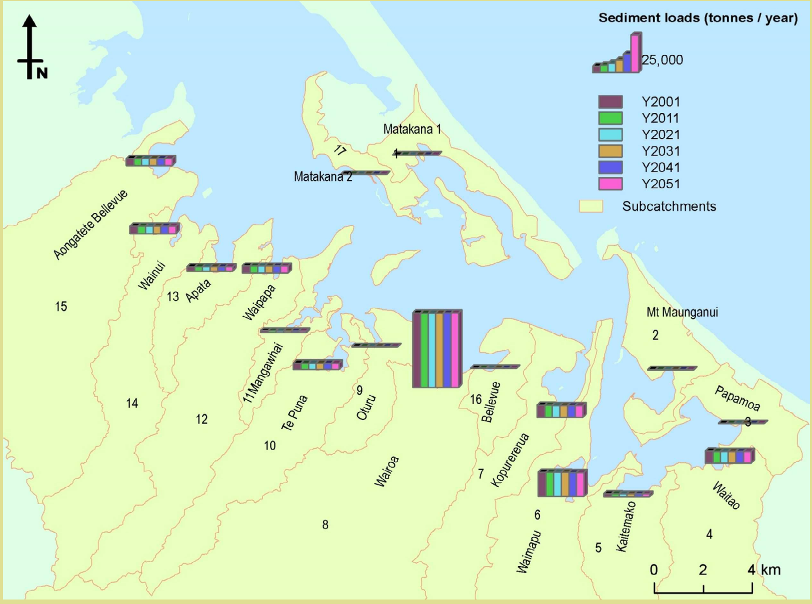
Key questions

- Where is most sediment generated?
- What affects the amount of sediment?
- What is the effect of future urbanisation?
- What is the effect of climate change?

Effect of urbanisation

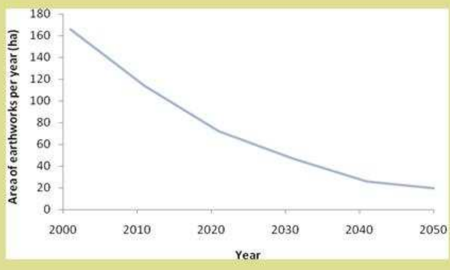


Effect of urbanisation by subcatchment



Why does urbanisation reduce load?

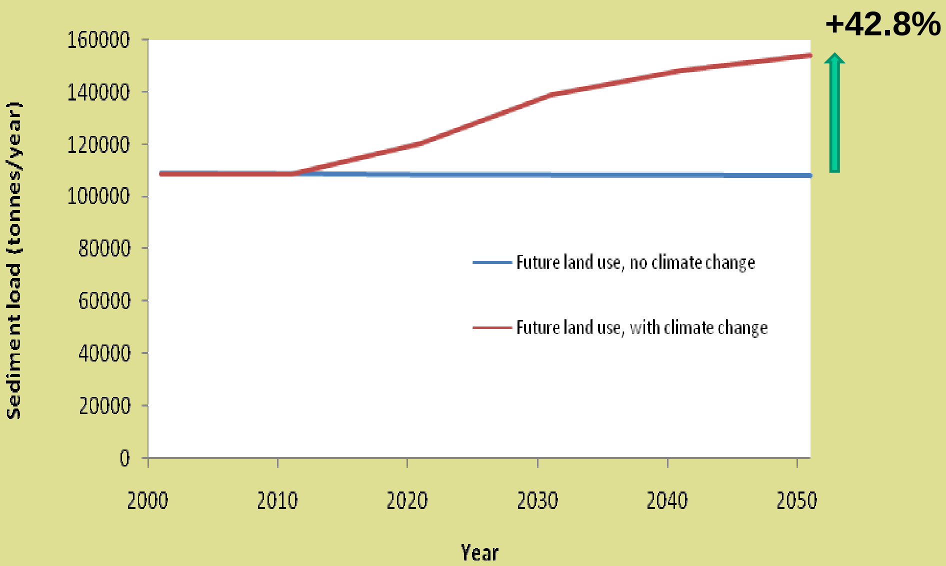
- Earthworks rate decreasing
- Pasture replaced with lawn and paving
- Effect is small because urban areas are small



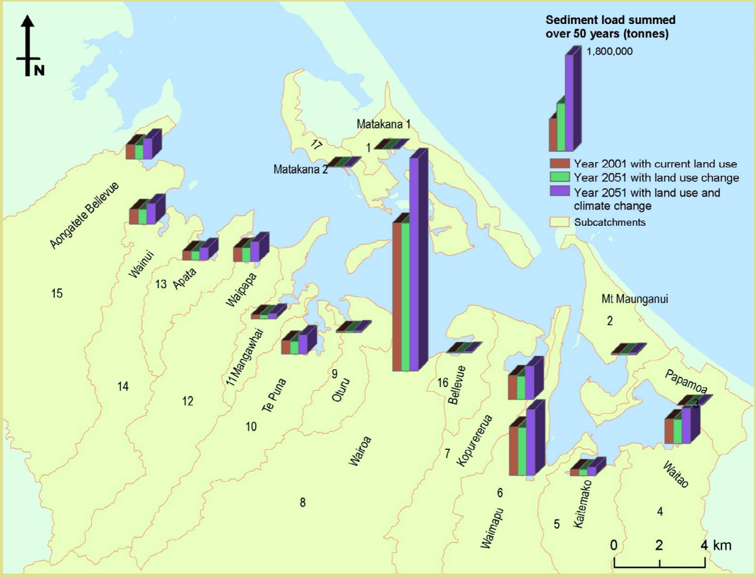
Key questions

- Where is most sediment generated?
- What affects the amount of sediment?
- What is the effect of future urbanisation?
- What is the effect of climate change?

Effect of climate change



Climate change effect by subcatchment



Why such a large change?

- Response dominated by large events
- Rain intensity for large events increases by 12%
- Runoff for large events increases by >12%
- Sediment load increases with runoff$^{2.5}$
- But….. somewhat conservative

Uncertainties and further work

- Stream erosion, especially bank erosion
- More long-term data for land use effects and rainfall-sediment relationship
- Slips
- Climate change effects
- Rain spatial distribution
- Validation of deposition component
- Validate silt pond performance
- Quarry parameters

Key findings of catchment sediment modelling

- The largest subcatchment (Wairoa) produces most sediment
- Most sediment (63%) is from pastoral land use
- Contribution from cropland and pines relatively small
- Earthworks contribution small (<0.5%)
- Urbanisation will results in a small decrease in sediment loads (down 0.75%)
- Climate change predicted to increase sediment loads substantially (42.8%)

Tauranga Harbour Sediment Study:
Assessment of predictions for management workshop
EBOP 13 July 2009

Harbour sedimentation modelling

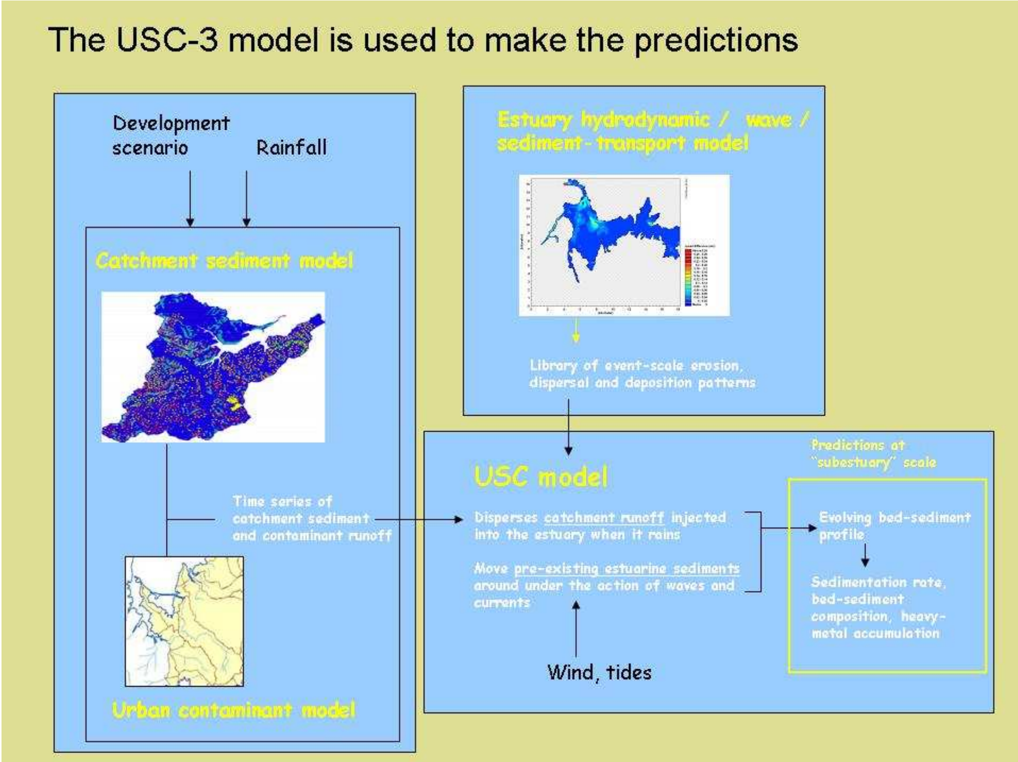
Malcolm Green

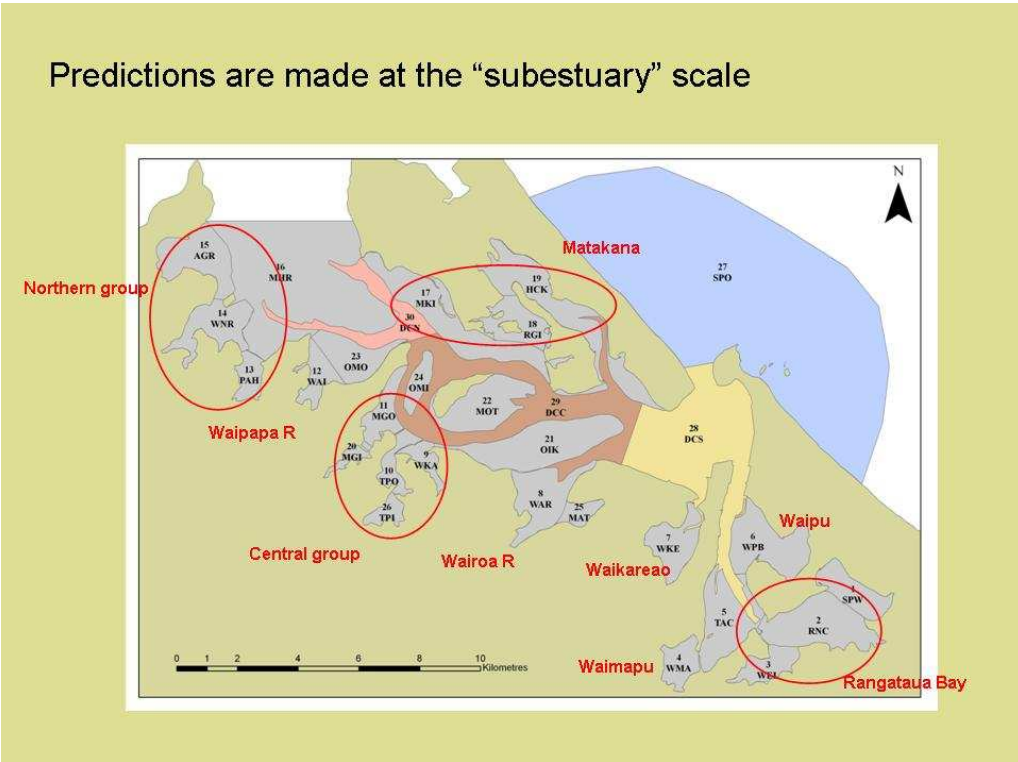
NIWA
Taihoro Nukurangi

Aim

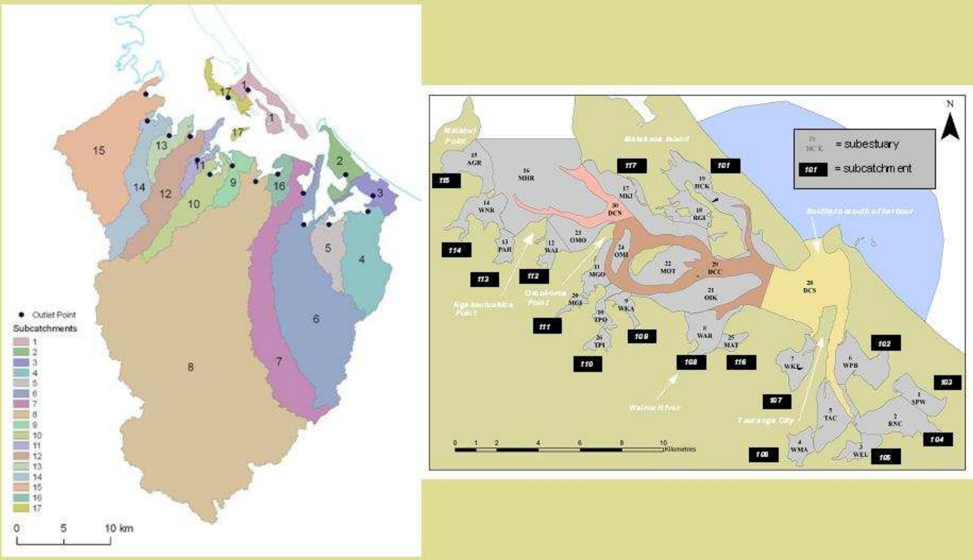
Predict sedimentation in the harbour for the period 2001-2051 under each of three scenarios:

Scenario	Landuse	Weather
1	Present-day (2001)	Present-day
2	SmartGrowth	Present-day
3	SmartGrowth	Climate change

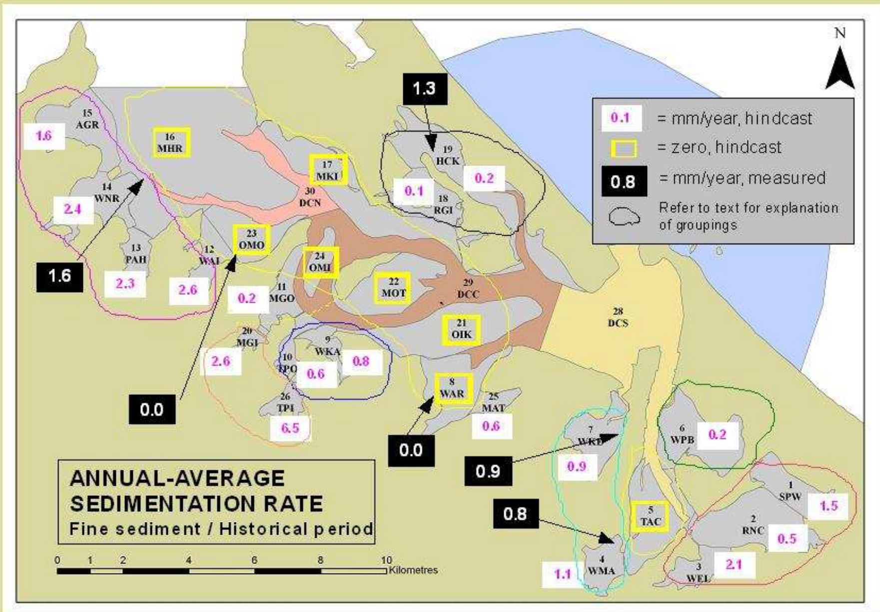

The USC-3 model is used to make the predictions
Development scenario
Rainfall
Catchment sediment model
Estuary hydrodynamic / wave / sediment-transport model
Library of event-scale erosion, dispersal and deposition patterns
Time series of catchment sediment and contaminant runoff
USC model
Predictions at "subestuary" scale
Disperses catchment runoff injected into the estuary when it rains
Move pre-existing estuarine sediments around under the action of waves and currents
Evolving bed-sediment profile
Sedimentation rate, bed-sediment composition, heavy-metal accumulation
Wind, tides
Urban contaminant model


Predictions are made at the "subestuary" scale
Northern group
Matakana
Waipapa R
Central group
Wairoa R
Waikareao
Waipu
Waimapu
Rangataua Bay
N
Kilometres

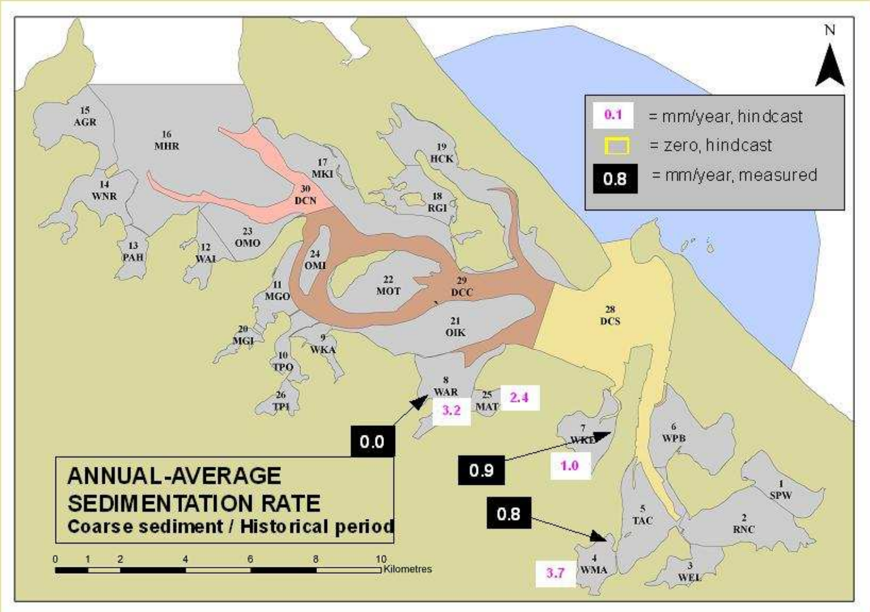
Subcatchments link to subestuaries



Model calibration



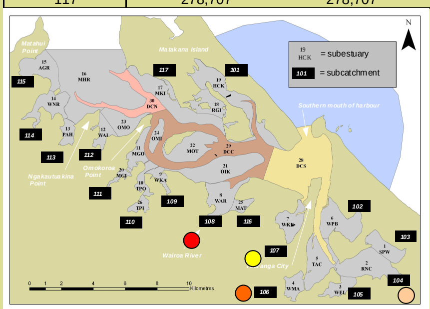
Model calibration



Sediment runoff into the harbour

FINE SEDIMENT

Subcatchment	Annual-average load (kg/year)			% change		
	Scenario 1 Current (2001) landuse No climate change	Scenario 2 Future landuse No climate change	Scenario 3 Future landuse Climate change	Landuse change (S2/S1)	Climate change (S3/S2)	Both (S3+S2)/S1
101	53,138	53,225	68,834	0.2	29.3	29.5
102	329,689	327,826	374,944	-0.6	14.4	13.7
103	275,049	284,679	353,042	3.5	24.0	28.4
104	7,160,301	7,111,379	8,945,375	-0.7	25.8	24.9
105	1,776,815	1,731,510	2,203,496	-2.5	27.3	24.0
106	14,649,806	14,578,067	17,578,178	-0.5	20.6	20.0
107	7,302,388	7,140,506	8,669,131	-2.2	21.4	18.7
108	44,183,562	44,178,484	53,931,825	0.0	22.1	22.1
109	390,134	390,132	497,815	0.0	27.6	27.6
110	3,819,758	3,817,694	4,745,218	-0.1	24.3	24.2
111	1,123,502	1,071,829	1,318,969	-4.6	23.1	17.4
112	4,228,386	4,237,168	5,196,643	0.2	22.6	22.9
113	2,682,534	2,682,429	3,313,085	0.0	23.5	23.5
114	4,433,307	4,433,179	5,399,622	0.0	21.8	21.8
115	4,068,928	4,067,793	5,149,544	0.0	26.6	26.6
116	225,350	171,649	209,990	-23.8	22.3	-6.8
117	278,707	278,707	354,671	0.0	27.3	27.3



Mainly negative or zero changes

All changes positive

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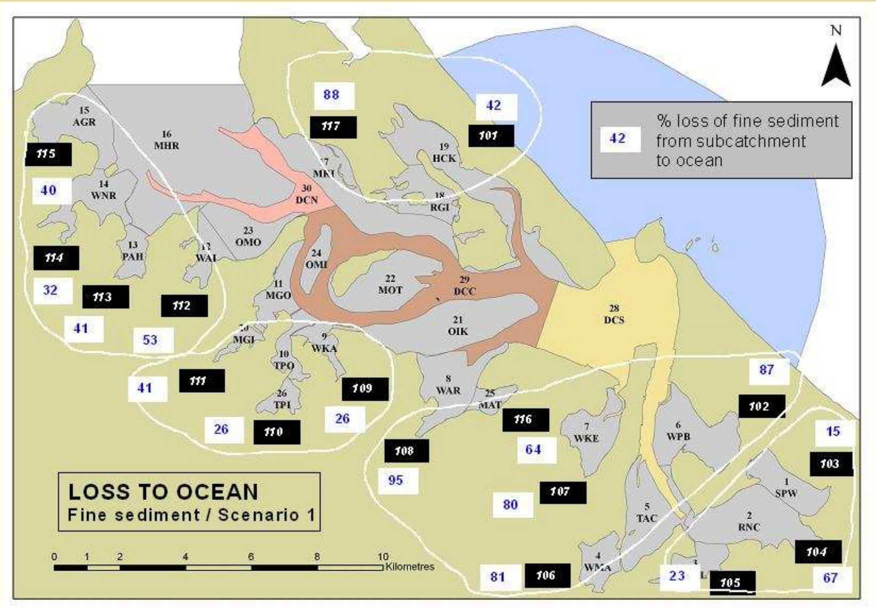
How then do these changes in sediment runoff from the catchment translate into changes in sedimentation in the harbour?

First, look at "how the harbour works", as it will help with the interpretation of the results…

How the harbour works



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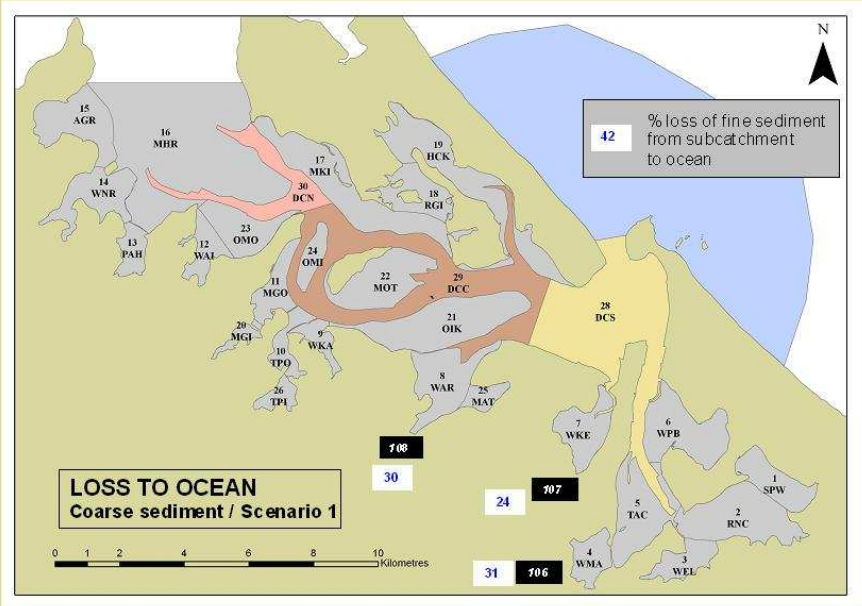
How the harbour works



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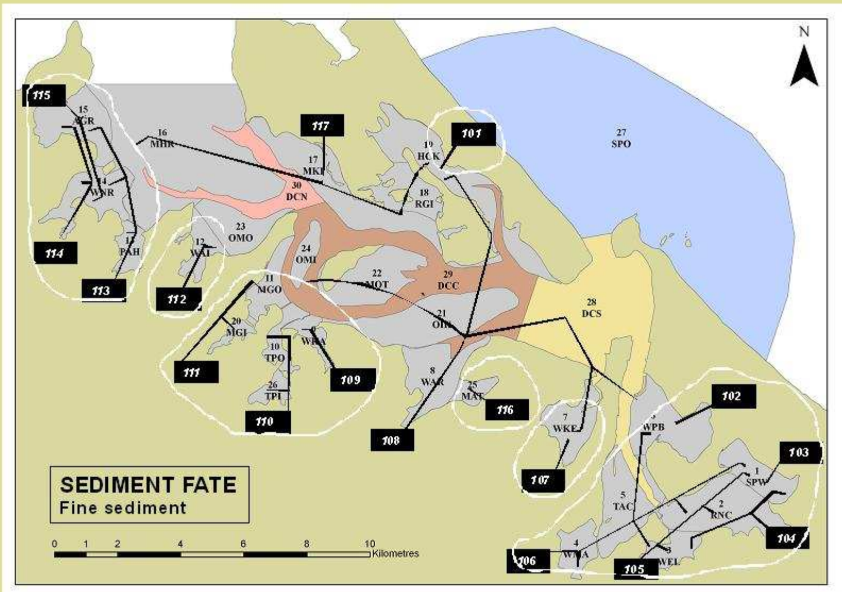
How the harbour works



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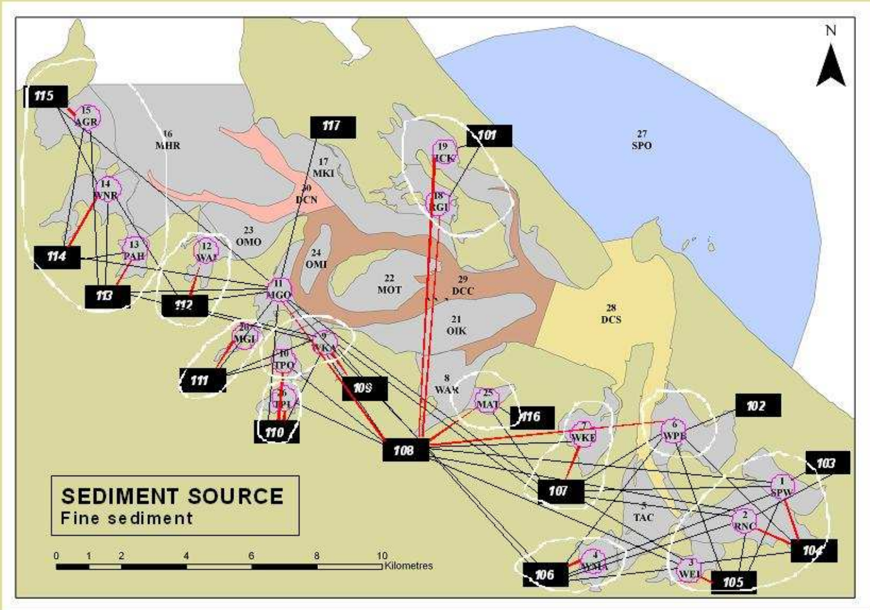
How the harbour works



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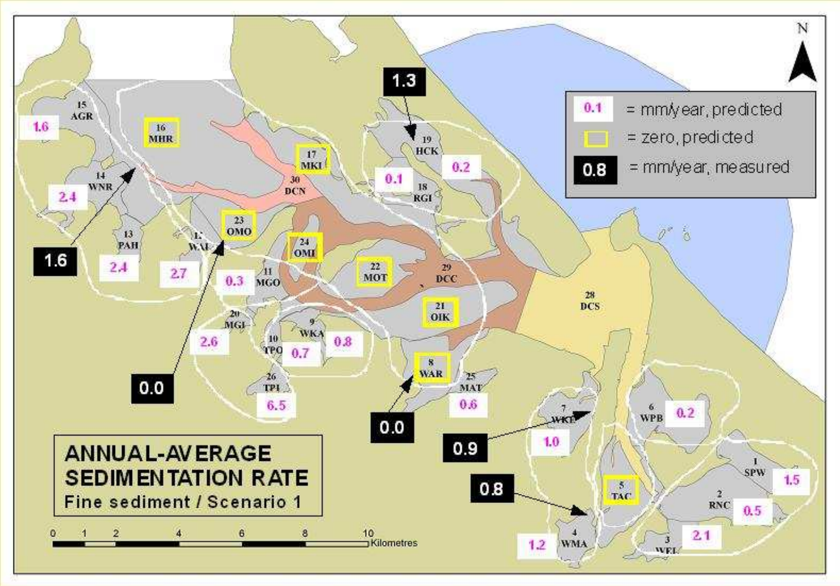
Now we come to results: change in annual-average sedimentation rate in each subestuary in response to changes in sediment runoff from the catchment

Results



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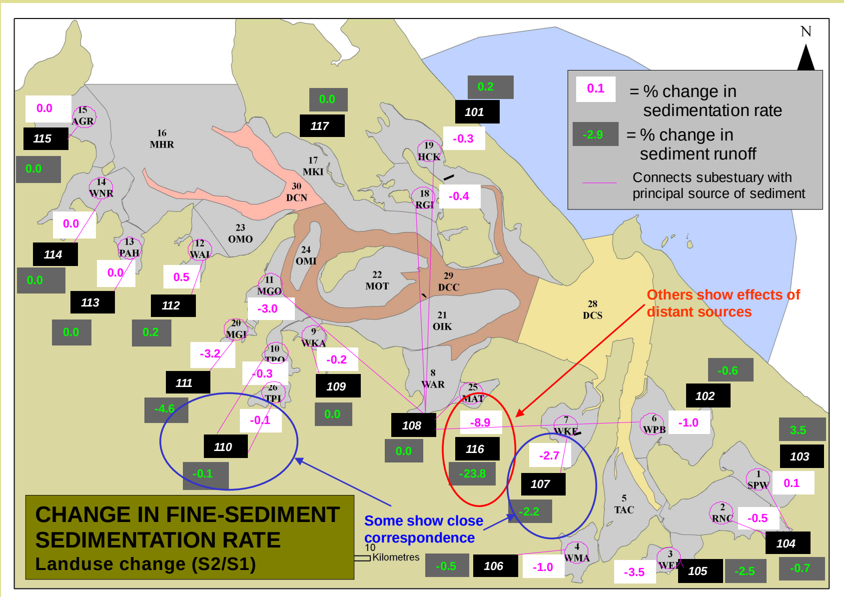
Results

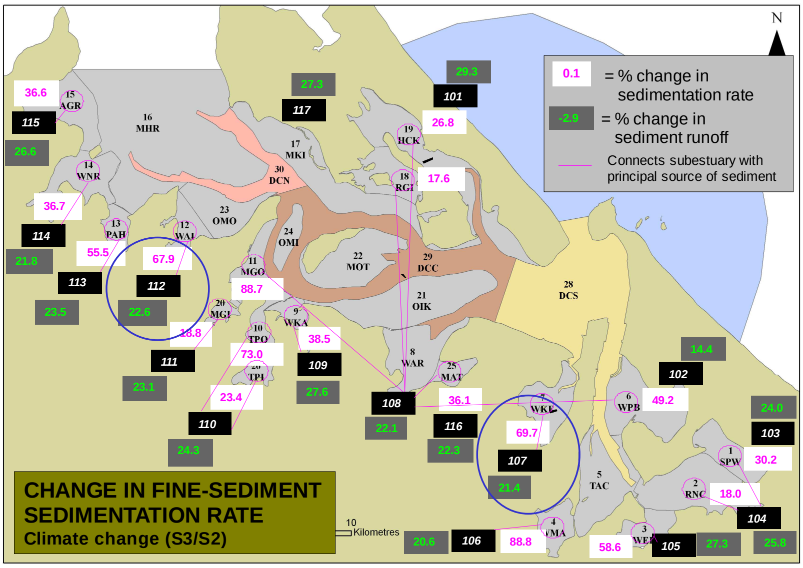
There is not necessarily a close correspondence between change in sedimentation rate and change in sediment runoff from adjacent subcatchment. Reasons: subestuaries deposit sediment from more than just adjacent subcatchment, and sediment-transport patterns can be changed by changes in sediment runoff.



Page 54, Results report

Results

"Positive imbalance" is a common response



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FINE SEDIMENT

Subcatchment	Annual-average load (kg/year)			% change		
	Scenario 1 Current (2001) landuse No climate change	**Scenario 2** Future landuse No climate change	**Scenario 3** Future landuse Climate change	**Landuse change** (S2/S1)	**Climate change** (S3/S2)	**Both** (S3+S2)/S1
101	53,138	53,225	68,834	0.2	29.3	29.5
102	329,689	327,826	374,944	-0.6	14.4	13.7
103	275,049	284,679	353,042	3.5	24.0	28.4
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105	1,776,815	1,731,510	2,203,496	-2.5	27.3	24.0
106	14,649,806	14,578,067	17,578,178	-0.5	20.6	20.0
107	7,302,388	7,140,506	8,669,131	-2.2	21.4	18.7
108	44,183,562	44,178,484	53,931,825	0.0	22.1	22.1
109	390,134	390,132	497,815	0.0	27.6	27.6
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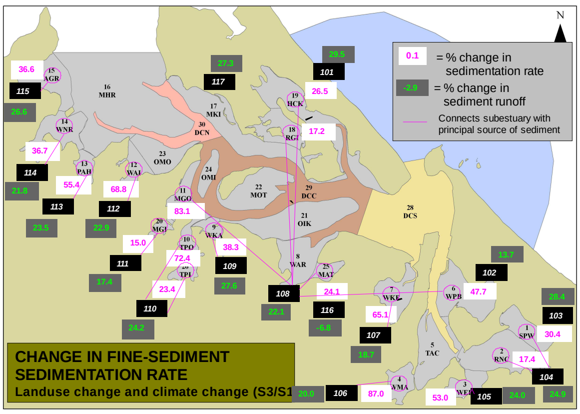
111	1,123,502	1,071,829	1,318,969	-4.6	23.1	17.4
112	4,228,386	4,237,168	5,196,643	0.2	22.6	22.9
113	2,682,534	2,682,429	3,313,085	0.0	23.5	23.5
114	4,433,307	4,433,179	5,399,622	0.0	21.8	21.8
115	4,068,928	4,067,793	5,149,544	0.0	26.6	26.6
116	225,350	171,649	209,990	-23.8	22.3	-6.8
117	278,707	278,707	354,671	0.0	27.3	27.3

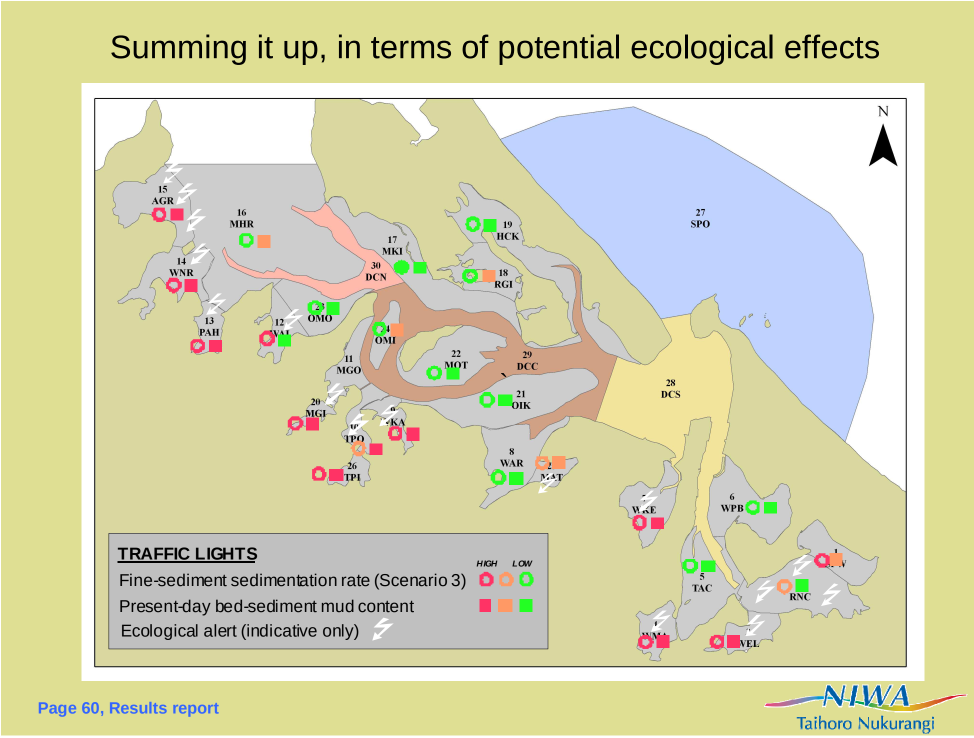
FINE SEDIMENT

Subestuary	Annual-average sedimentation rate (mm/year)			% change		
	Scenario 1 Current (2001) landuse No climate change	**Scenario 2** Future landuse No climate change	**Scenario 3** Future landuse Climate change	**Landuse change** (S2/S1)	**Climate change** (S3/S2)	**Both** (S3+S2)/S1
1	1.48	1.48	1.93	0.1	30.2	30.4
2	0.50	0.50	0.59	-0.5	18.0	17.4
3	2.11	2.04	3.23	-3.5	58.6	53.0
4	1.15	1.14	2.16	-1.0	88.8	87.0
5	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
6	0.22	0.22	0.33	-1.0	49.2	47.7
7	1.01	0.98	1.66	-2.7	69.7	65.1
8	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
9	0.77	0.77	1.07	-0.2	38.5	38.3
10	0.71	0.71	1.22	-0.3	73.0	72.4
11	0.25	0.25	0.47	-3.0	88.7	83.1
12	2.67	2.68	4.50	0.5	67.9	68.8
13	2.38	2.38	3.69	0.0	55.5	55.4
14	2.36	2.36	3.22	0.0	36.7	36.7
15	1.63	1.63	2.22	0.0	36.6	36.6
16	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
17	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
18	0.06	0.06	0.08	-0.4	17.6	17.2
19	0.19	0.19	0.24	-0.3	26.8	26.5
20	2.55	2.47	2.93	-3.2	18.8	15.0
21	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
22	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
23	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
24	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
25	0.60	0.55	0.74	-8.9	36.1	24.1
26	6.51	6.50	8.03	-0.1	23.4	23.4



FINE SEDIMENT

Main source subcatchment	Subestuary	Main driver of change
104	1	Climate change and landuse change additive (increase)
104	2	Climate change dominant (increase)
105	3	Climate change dominant (increase)
106	4	Climate change dominant (increase)
-	5	-
108	6	Climate change dominant (increase)
107	7	Climate change dominant (increase)
-	8	-
109	9	Climate change dominant (increase)
110	10	Climate change dominant (increase)
108	11	Climate change dominant (increase)
112	12	Climate change and landuse change additive (increase)
113	13	Climate change dominant (increase)
114	14	Climate change dominant (increase)
115	15	Climate change dominant (increase)
-	16	-
-	17	-
108	18	Climate change dominant (increase)
108	19	Climate change dominant (increase)
111	20	Climate change dominant (increase)
-	21	-
-	22	-
-	23	-
-	24	-
108	25	Climate change dominant (increase)
110	26	Climate change dominant (increase)


Summing it up, in terms of potential ecological effects
N
15
AGR
16
MHR
14
WNR
13
PAH
17
MKI
30
DCN
19
HCK
18
RGI
27
SPO
OMO
12
OMI
11
MGO
22
MOT
29
DCC
21
OIK
28
DCS
20
MGI
TPO
26
TPI
8
WAR
6
WPB
5
TAC
RNC
TRAFFIC LIGHTS
HIGH
LOW
Fine-sediment sedimentation rate (Scenario 3)
Present-day bed-sediment mud content
Ecological alert (indicative only)
Page 60, Results report
NIWA
Taihoro Nukurangi

6.2 Appendix 6.2: Summary of subestuary information: effects of landuse and climate change on subestuaries and overall potential scale of adverse effects

Tables that summarise for each of the 26 subestuaries the sources of catchment derived sediment. The tables also show for each subestuary, under landuse and climate change in the next 50 years, how the annual-average fine-sediment runoff from the largest source catchment will change, what grainsize of sediment will be deposited in the subestuary, how the annual-average fine-sediment accumulation rate (mm/yr) will change, and the overall potential scale (low, medium and high) of adverse effects that are predicted to occur.

SUBESTUARY: Speedway (1-SPW)

The northeastern intertidal flats of Rangataua Bay, adjacent to the speedway. This is fringed by mangroves, which are thick in places. Southern sector of Tauranga Harbour.

Adjacent subcatchment	(103-PAP) Papamoa
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	15%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(104-WTO) Waitao	47%	4
(106-WMP) Waimapu	31%	2
(103-PAP) Papamoa	12%	15
(108-WAR) Wairoa	7%	1
(105-KMK) Kaitemako	1%	10
(107-KOP) Kopurererua	1%	3
Others	<1%	

Mud content / mean grainsize	14.0% / 0.27 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	1.48
SmartGrowth landuse / present-day weather (S2)	1.48
SmartGrowth landuse / climate change (S3)	1.93

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH

Rangataua Bay, which encompasses subestuaries 3–WEL, 2–RNC and 1–SPW, is presently muddier around the fringes and in localised embayments, (the seabed mud content in Welcome Bay and Speedway is currently 31.4% and 14.0%, respectively). The muddy fringes will expand into the central reaches (currently 6.9% mud) under high fine-sediment sedimentation rates (3.23 mm/year for 3–WEL and 1.93 mm/year for 1–SPW, under the combined influence of landuse change and climate change). This will foster a corresponding spread of mangroves.

SUBESTUARY: Rangataua Bay (2-RNC)

Central reaches of Rangataua Bay. This receives runoff from a number of streams (including Waitao) and is fringed by mangroves.

Southern sector of Tauranga Harbour

Adjacent subcatchment	(104-WTO) Waitao
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	67%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(104-WTO) Waitao	79%	4
(106-WMP) Waimapu	16%	2
(105-KMK) Kaitemako	2%	10
(108-WAR) Wairoa	2%	1
(107-KOP) Kopurererua	1%	3
Others	<1%	

Mud content / mean grainsize	6.9% / 0.32 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.50
SmartGrowth landuse / present-day weather (S2)	0.50
SmartGrowth landuse / climate change (S3)	0.59

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH
Rangataua Bay, which encompasses subestuaries 3–WEL, 2–RNC and 1–SPW, is presently muddier around the fringes and in localised embayments, (the seabed mud content in Welcome Bay and Speedway is currently 31.4% and 14.0%, respectively). The muddy fringes will expand into the central reaches (currently 6.9% mud) under high fine-sediment sedimentation rates (3.23 mm/year for 3–WEL and 1.93 mm/year for 1–SPW, under the combined influence of landuse change and climate change). This will foster a corresponding spread of mangroves.

SUBESTUARY: Welcome Bay (3-WEL)

Welcome Bay, which is fringed by mangroves.

Southern sector of Tauranga Harbour

Adjacent subcatchment	(105-KMK) Kaitemako
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	23%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(105-KMK) Kaitemako	47%	10
(106-WMP) Waimapu	26%	2
(104-WTO) Waitao	21%	4
(108-WAR) Wairoa	5%	1
(107-KOP) Kopurererua	1%	3
Others	<1%	

Mud content / mean grainsize	31.4% / 0.27 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	2.11
SmartGrowth landuse / present-day weather (S2)	2.04
SmartGrowth landuse / climate change (S3)	3.23

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH

Rangataua Bay, which encompasses subestuaries 3–WEL, 2–RNC and 1–SPW, is presently muddier around the fringes and in localised embayments, (the seabed mud content in Welcome Bay and Speedway is currently 31.4% and 14.0%, respectively). The muddy fringes will expand into the central reaches (currently 6.9% mud) under high fine-sediment sedimentation rates (3.23 mm/year for 3–WEL and 1.93 mm/year for 1–SPW, under the combined influence of landuse change and climate change). This will foster a corresponding spread of mangroves.

SUBESTUARY: Waimapu (4-WMA)

Waimapu estuary, which receives runoff from Waimapu Stream and which is enclosed at the mouth by the SH2 embankment.

Southern sector of Tauranga Harbour

Adjacent subcatchment	(106-WMP) Waimapu
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	81%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(106-WMP) Waimapu	99%	2
Others	<1%	

Mud content / mean grainsize	30.3% / 0.34 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	1.15
SmartGrowth landuse / present-day weather (S2)	1.14
SmartGrowth landuse / climate change (S3)	2.16

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH

The seabed in subestuary 4–WMA is currently 30.3% mud and this will further increase under the combined influence of landuse change and climate change with a fine-sediment sedimentation rate of 2.16 mm/year. This will be manifest as spreading of mud into the relatively sandier central reaches and the reaches near the outlet of the embayment. Any increase in mud content may be mitigated by deposition of coarse sediment brought down by the Waimapu Stream in flood.

SUBESTUARY: Tauranga City foreshore (5-TAC)

Intertidal flats that run along the Tauranga City foreshore.

Southern sector of Tauranga Harbour	
Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A

Mud content / mean grainsize	9.8% / 0.40 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2)	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW
The model predicts that fine sediments will not accumulate on the intertidal flats that run along the Tauranga City foreshore (5–TAC).

SUBESTUARY: Waipu Bay (6-WPB)

Waipu Bay, which lies across the main channel from the Tauranga City foreshore.

Southern sector of Tauranga Harbour

Adjacent subcatchment	(102-MMI) Mount Maunganui
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	87%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(108-WAR) Wairoa	48%	1
(106-WMP) Waimapu	26%	2
(102-MMI) Mount Maunganui	10%	13
(107-KOP) Kopurererua	7%	3
(104-WTO) Waitao	5%	4
(105-KMK) Kaitemako	3%	10
Others	<1%	

Mud content / mean grainsize 8.1% / 0.32 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.22
SmartGrowth landuse / present-day weather (S2)	0.22
SmartGrowth landuse / climate change (S3)	0.33

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

Predicted fine-sediment sedimentation rate is low in 6–WPB (0.33 mm/year under the combined influence of landuse change and climate change). Bed-sediment mean grainsize is presently large at 0.32 mm and the mud content is low at 8.1%. These will only change slowly.

SUBESTUARY: Waikareao (7-WKE)

Waikareao estuary, which receives runoff from Kopurererua Stream.

Waikareao

Adjacent subcatchment	(107-KOP) Kopurererua
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	80%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(107-KOP) Kopurererua	82%	3
(108-WAR) Wairoa	18%	1
Others	<1%	

Mud content / mean grainsize	20.8% / 0.16 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	1.01
SmartGrowth landuse / present-day weather (S2)	0.98
SmartGrowth landuse / climate change (S3)	1.66

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH

The mud content of the seabed in subestuary 7–WKE is currently 20.8% and this will increase under a fine-sediment sedimentation rate of 1.66 mm/year under the combined influence of landuse change and climate change. This will be manifest as spreading of mud into the relatively sandier central reaches and the reaches near the outlet of the embayment. Any increase in mud content may be mitigated by deposition of coarse sediment brought down by the Kopurererua Stream in flood. However, Green (2009) thought that the coarse-sediment runoff from the Kopurererua subcatchment is being over-estimated in the model.

SUBESTUARY: Mouth of Wairoa River (8-WAR)

At the mouth of the Wairoa River. This is an area of extensive, exposed sandflats.

Mouth of Wairoa River

Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A

Mud content / mean grainsize	3.5% / 0.30 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2)	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW
Fine sediment is not predicted to accumulate at the mouth of the Wairoa River in subestuary 8–WAR, because it is exposed and subject to flushing flows. In addition to that, coarse sediment brought down by the Wairoa River in flood deposits in this area. Hence, the already sandy bed (just 3.5% mud content) will not become muddier.

NIWA
Taihoro Nukurangi

SUBESTUARY: Waikaraka (9-WKA)

Like 10–TPO, this subestuary is partially enclosed by a spit complex at the mouth, and is being colonised by mangroves.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment	(109-OTU) Oturu
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	26%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(109-OTU) Oturu	68%	12
(108-WAR) Wairoa	20%	1
(110-TPU) Te Puna	5%	8
Others	<1%	

Mud content / mean grainsize	35.7% / 0.27 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.77
SmartGrowth landuse / present-day weather (S2)	0.77
SmartGrowth landuse / climate change (S3)	1.07

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH
Subestuary 9–WKA is similar to 10–TPO: the predicted fine-sediment sedimentation rate under the combined influence of landuse change and climate is relatively small (1.07 mm/year), but it too, has a recent history of mangrove spread and a high amenity value. Climate change is predicted to cause a significant increase in sedimentation here. As was the case for 10–TPO, should the spit complex at the mouth of 9–WKA continue to prograde, the embayment enclosed by the spit may become a more effective sediment trap.

SUBESTUARY: Te Puna (outer) (10-TPO)

Partially enclosed by a spit complex at the mouth, and is being colonised by mangroves.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment	(110-TPU) Te Puna
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	26%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(110-TPU) Te Puna	98%	8
(108-WAR) Wairoa	1%	1
Others	<1%	

Mud content / mean grainsize	22.3% / 0.28 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.71
SmartGrowth landuse / present-day weather (S2)	0.71
SmartGrowth landuse / climate change (S3)	1.22

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH

Subestuary 10–TPO is partially enclosed by a spit complex at the mouth. The predicted sedimentation rate under the combined influence of landuse change and climate change is small compared to subestuaries to the north (1.22 mm/year, compared to 2–3 mm/year), but still may be a matter of concern given the recent history of mangrove spread here, and high amenity values. Should the spit complex at the mouth continue to prograde, the embayment enclosed by the spit may become a more effective sediment trap.

SUBESTUARY: Mangawhai Bay (outer) (11-MGO)

Runs along the east of Omokoroa Peninsula. This is open and flat, and exposed to winds and strong tidal currents.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment	(111-MGW) Mangawhai
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	41%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(108-WAR) Wairoa	59%	1
(111-MGW) Mangawhai	24%	11
(110-TPU) Te Puna	3%	8
(107-KOP) Kopurererua	3%	3
(115-AGR) Aongatete	3%	7
(112-WAI) Waipapa	2%	6
(114-WNR) Wainui	1%	5
(113-APA) Apata	1%	9
(106-WMP) Waimapu	1%	2
(117-MKW) Matakana 2	1%	14
Others	<1%	
Mud content / mean grainsize	23.7% / 0.19 mm	

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.25
SmartGrowth landuse / present-day weather (S2)	0.25
SmartGrowth landuse / climate change (S3)	0.47

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

MEDIUM
Predicted fine-sediment sedimentation rate is low in 11–MGO (0.47 mm/year under the combined influence of landuse change and climate change), which suggests that bed-sediment mud content will increase and mean grainsize will decrease only slowly. The present-day mud content of >20% in this region seems somewhat at odds with that prediction; an explanation may be that this subestuary is rather poorly defined, stretching as it does from the East Coast Main Trunk rail line embankment, which is sheltered, to Omokoroa Point, which is exposed. An ecological alert is placed at the sheltered end of 11–MGO, where fine sediment may escape from 20–MGI (enclosed by the rail line embankment) and deposit.

SUBESTUARY: Mouth of Waipapa River (12-WAI)

Mouth of the Waipapa River. There is a depositional lobe associated with the river, and the inner reaches are filled with mangroves.

Northern sector of (southern) Tauranga Harbour

Adjacent subcatchment	(112-WAI) Waipapa
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	53%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(112-WAI) Waipapa	99%	6
Others	<1%	

Mud content / mean grainsize	6.3% / -

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	2.67
SmartGrowth landuse / present-day weather (S2)	2.68
SmartGrowth landuse / climate change (S3)	4.50

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

HIGH

The predicted fine-sediment sedimentation rate under the combined effcts of landuse change and climate change is high (4.50 mm/year) which represents a large change relative to the Scenario 1 baseline (68.8%). Hancock et al. report a low mud content for the bed sediments here (only 6.3%), although this estimate is biased towards the outer, sandier, parts of the subestuary. Continued deposition of fine sediment will encroach on to these outer areas, altering habitat and fostering the spread of mangroves.

SUBESTUARY: Pahoia Beach Road (13-PAH)

Sheltered embayment accessed from Pahoia Beach Road. The inner part of the embayment is largely occupied by a centrally-located stand of mangroves, but the mouth of the embayment is open.

Northern sector of (southern) Tauranga Harbour

Adjacent subcatchment	(113-APA) Apata
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	41%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(113-APA) Apata	98%	9
(114-WNR) Wainui	1%	5
Others	<1%	

Mud content / mean grainsize	48.1% / 0.06 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	2.38
SmartGrowth landuse / present-day weather (S2)	2.38
SmartGrowth landuse / climate change (S3)	3.69

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

MEDIUM

Subestuary 13–PAH is predicted to experience a large increase of >+50% in fine-sediment sedimentation rate under the combined influence of landuse change and climate change, to 3.67 mm/year. As was the case in 14–WNR to the north, the mud content of the seabed here is already high (48.1%), which will increase in time. The ecological effects will possibly be limited, given that the seabed is already quite muddy. However, fine sediment will also encroach into the mouth of the embayment, which currently features sandier habitats.

SUBESTUARY: Mouth of Wainui River (14-WNR)

Dual embayment at the mouth of the Wainui River. The inner embayment is largely choked with mangroves. The outer embayment features complicated sandbanks and islands.
Northern sector of (southern) Tauranga Harbour

Adjacent subcatchment (114-WNR) Wainui

Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1) 32%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(114-WNR) Wainui	95%	5
(113-APA) Apata	3%	9
(115-AGR) Aongatete	1%	7
(112-WAI) Waipapa	1%	6
Others	<1%	

Mud content / mean grainsize 43.7% / -

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	2.36
SmartGrowth landuse / present-day weather (S2)	2.36
SmartGrowth landuse / climate change (S3)	3.22

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

MEDIUM
The fine-sediment sedimentation rate in subestuary 14–WNR at the mouth of the Wainui River is predicted to increase substantially (+36.7%, to 3.22 mm/year) under the combined influence of landuse change and climate change. The mud content of the seabed here is already 43.7% on average, which will increase in time. Since the mud content of the seabed is already high, there may not be further significant ecological effects. However, fine sediment will also encroach into the outer embayment, into the area that currently features complicated sandbanks and islands, and towards 16–MHR.

SUBESTUARY: Aongatete (15-AGR)

Embayment at the mouth of the Aongatete River. Sediment discharged from the river is prograding into the embayment, and being colonised by mangroves.

Northern sector of (southern) Tauranga Harbour

Adjacent subcatchment	(115-AGR) Aongatete
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	40%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(115-AGR) Aongatete	97%	7
(114-WNR) Wainui	1%	5
(113-APA) Apata	1%	9
Others	<1%	
Mud content / mean grainsize	27.1% / -	

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	1.63
SmartGrowth landuse / present-day weather (S2)	1.63
SmartGrowth landuse / climate change (S3)	2.22

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

MEDIUM

The fine-sediment sedimentation rate in subestuary 15–AGR at the mouth of the Aongatete River is predicted to increase substantially (+36.6%, to 2.22 mm/year) under the combined influence of landuse change and climate change. The mud content of the seabed here is already 27.1% on average, which will increase in time. This is likely to occur through further encroachment of fine sediment beyond the mouth of the river, towards 16–MHR, causing habitat change and continued mangrove spread.

SUBESTUARY: Middle-harbour sandbanks (16-MHR)

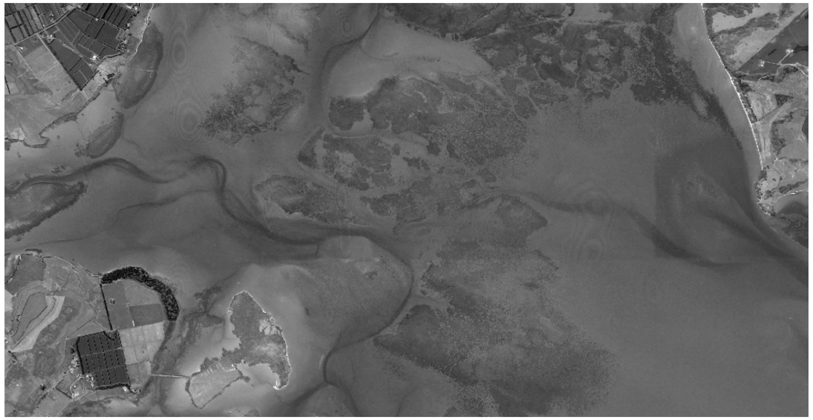
Middle-harbour sandbanks.

Northern sector of (southern) Tauranga Harbour

Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A



Mud content / mean grainsize	14.4% / 0.18 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2)	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

The model predicts that fine sediments will not accumulate on the middle-harbour sandbanks (16–MHR).

SUBESTUARY: Matakana Island) (17-MKI)

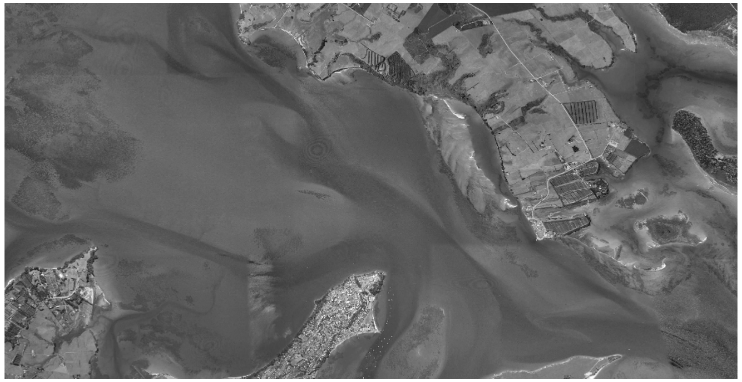
Intertidal flats that run along the western, central section of Matakana Island.

Matakana Island

Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A



Mud content / mean grainsize 3.4% / 0.40 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2)	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

The model predicts that fine sediments will not accumulate on the intertidal flats that run along the western, central section of Matakana Island (17–MKI).

SUBESTUARY: Rangiwaea Island (18-RGI)

Subestuary 18–RGI lies on the opposite (western) side of Rangiwaea Island from Hunters Creek.

Matakana Island

Adjacent subcatchment	(101-MKE) Matakana 1
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	42%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(108-WAR) Wairoa	65%	1
(107-KOP) Kopurererua	5%	3
(112-WAI) Waipapa	5%	6
(114-WNR) Wainui	4%	5
(110-TPU) Te Puna	4%	8
(113-APA) Apata	3%	9
(106-WMP) Waimapu	3%	2
(115-AGR) Aongatete	3%	7
(117-MKW) Matakana 2	3%	14
(104-WTO) Waitao	2%	4
(111-MGW) Mangawhai	1%	11
Others	<1%	

Mud content / mean grainsize 10.8 % / 0.32 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.06
SmartGrowth landuse / present-day weather (S2)	0.06
SmartGrowth landuse / climate change (S3)	0.08

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

Predicted fine-sediment sedimentation rate in both 18–RGI and 19–HCK is small (0.08 mm/year and 0.24 mm/year, respectively). In both of these subestuaries the bed-sediment mean grainsize is large (0.32 mm in both) and the mud content is low (10.8% and 8.5%, respectively). These will only change slowly.

SUBESTUARY: Hunters Creek (19-HCK)

Hunters Creek, which penetrates the southern end of Matakana Island.

Matakana Island

Adjacent subcatchment	(101-MKE) Matakana 1
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	42%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(108-WAR) Wairoa	80%	1
(101-MKE) Matakana 1	4%	17
(107-KOP) Kopurererua	4%	3
(106-WMP) Waimapu	4%	2
(104-WTO) Waitao	2%	4
(110-TPU) Te Puna	1%	8
(112-WAI) Waipapa	1%	6
(114-WNR) Wainui	1%	5
(115-AGR) Aongatete	1%	7
Others	<1%	

Mud content / mean grainsize 8.5% / 0.32 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.19
SmartGrowth landuse / present-day weather (S2	0.19
SmartGrowth landuse / climate change (S3)	0.24

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

Predicted fine-sediment sedimentation rate in both 18–RGI and 19–HCK is small (0.09 mm/year and 0.24 mm/year, respectively). In both of these subestuaries the bed-sediment mean grainsize is large (0.32 mm in both) and the mud content is low (10.8% and 8.5%, respectively). These will only change slowly.

SUBESTUARY: Mangawhai Bay inner (20-MGI)

Enclosed by the East Coast Main Trunk rail line embankment; virtually disconnected from the adjoining outer embayment (i.e., 11–MGO, to the east of the rail line). It is an effective sediment trap.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment	(111-MGW) Mangawhai
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	41%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(111-MGW) Mangawhai	67%	11
(108-WAR) Wairoa	19%	1
(110-TPU) Te Puna	4%	8
Others	<1%	

Mud content / mean grainsize	-

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	2.55
SmartGrowth landuse / present-day weather (S2	2.47
SmartGrowth landuse / climate change (S3)	2.93

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

The two subestuaries enclosed by the East Coast Main Trunk rail line embankment (20–MGI and 26–TPI) are already choked with mud. Further deposition of fine sediment here will continue to push these subestuaries towards the end stages of stabilisation by vegetation.

SUBESTUARY: Oikimoki Point (21-OIK)

Mid-harbour sandbank that lies off Oikimoke Point.

Mouth of Wairoa River

Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A

Mud content / mean grainsize	4.4% / 0.24 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

The model predicts that fine sediments will not accumulate in the central reaches of the (southern) harbour, which includes 21–OIK.

SUBESTUARY: Sandbank east of Motuhoa Island (22-MOT)

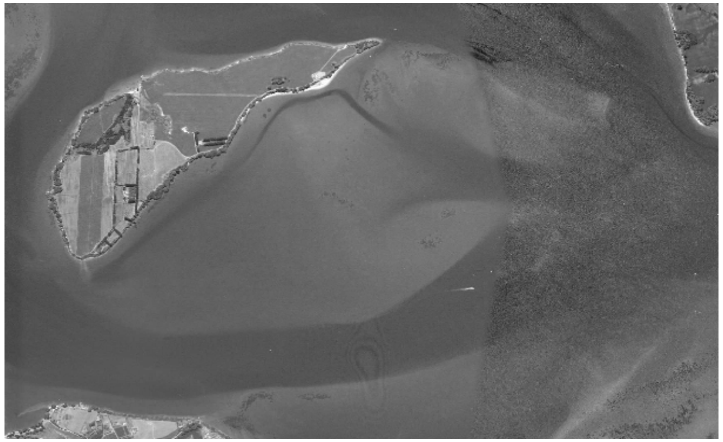
Mid-harbour sandbank that lies to the east of Motuhoa Island.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A



Mud content / mean grainsize	0.7% / 0.24 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

The model predicts that fine sediments will not accumulate in the central reaches of the (southern) harbour, which includes 22–MOT.

SUBESTUARY: West of Omokoroa Peninsula (23-OMO)

Open intertidal flats between the mouth of the Waipapa River and the western shore of Omokoroa Peninsula.

Northern sector of (southern) Tauranga Harbour

Adjacent subcatchment	(112-WAI) Waipapa
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	53%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A

Mud content / mean grainsize	4.3% / 0.31 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

MEDIUM

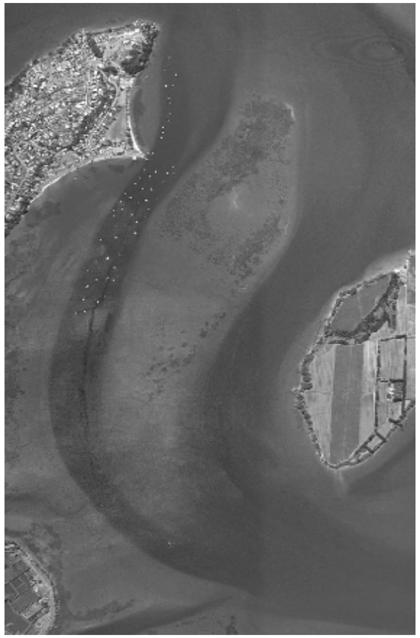
The model predicts that fine sediments will not accumulate in the open intertidal flats between the mouth of the Waipapa River and the western shore of Omokoroa Peninsula (23–OMO). Nevertheless, fine sediment deposited within 12–WAI, which lies adjacent, will encroach in this direction.

SUBESTUARY: Sandbank east of Omokoroa Peninsula (24-OMI)

Sandbank between the eastern shore of Omokoroa Peninsula and the western shore of Motuhoa Island.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment	N/A
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	N/A



Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
N/A	N/A	N/A

Mud content / mean grainsize	14.1% / 0.33 mm

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.00
SmartGrowth landuse / present-day weather (S2)	0.00
SmartGrowth landuse / climate change (S3)	0.00

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW
The model predicts that fine sediments will not accumulate on the sandbank between the eastern shore of Omokoroa Peninsula and the western shore of Motuhoa Island (24–OMI). The mud content here is presently moderate at 14.1%.

SUBESTUARY: Matua (25-MAT)

Small embayment near the mouth of the Wairoa River, formed by the Matua peninsula. It is open but fringed with mangroves.

Mouth of Wairoa River

Adjacent subcatchment	(116-MAT) Matua	
Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1)	64%	
Fine sediment sources		
Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(108-WAR) Wairoa	72%	1
(116-MAT) Matua	1%	16
(107-KOP) Kopurererua	1%	3
Others	<1%	
Mud content / mean grainsize	10.8% / 0.29 mm	

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	0.60
SmartGrowth landuse / present-day weather (S2)	0.55
SmartGrowth landuse / climate change (S3)	0.74

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

MEDIUM

Subestuary 25–MAT is also at the mouth of the Wairoa River, and it also receives some coarse sediment brought down by the Wairoa River in flood. However, the fine-sediment sedimentation rate is moderate (0.74 mm/year under the combined influence of landuse change and climate change). The seabed will become muddier as fine sediment spreads from the inner edges of the embayment, where mangroves have already established.

SUBESTUARY: Te Puna (inner) (26-TPI)

The inner pocket of Te Puna estuary that is enclosed by the East Coast Main Trunk rail line embankment. The pocket is reached via Jess Road. It is virtually disconnected from its adjoining outer embayment (to the east of the rail line), and is an effective sediment trap.

Central sector of (southern) Tauranga Harbour

Adjacent subcatchment (110-TPU) Te Puna

Loss of fine sediment to ocean from adjacent subcatchment (Scenario 1) 26%

Fine sediment sources

Subcatchment	*Supplies % of fine sediment deposited in subestuary*	*Ranking of subcatchment by total sediment runoff to harbour*
(110-TPU) Te Puna	98%	8
(108-WAR) Wairoa	1%	1
Others	<1%	

Mud content / mean grainsize -

Sedimentation

Scenario	*Annual-average fine-sediment sedimentation rate (mm/year)*
Present-day weather (S1)	6.51
SmartGrowth landuse / present-day weather (S2)	6.50
SmartGrowth landuse / climate change (S3)	8.03

Overall potential scale (HIGH, MEDIUM, LOW) of adverse effects under landuse and climate change

LOW

The two subestuaries enclosed by the East Coast Main Trunk rail line embankment (20–MGI and 26–TPI) are already choked with mud. Further deposition of fine sediment here will continue to push these subestuaries towards the end stages of stabilisation by vegetation.

6.3 Appendix 6.3: Summary of subcatchment information: effects of landuse and climate change on subcatchments and mitigation options/opportunities in the subcatchments

Tables that summarise for each of the 17 subcatchments, the quantity of sediment runoff lost to the ocean, a ranking in terms of overall fine sediment contribution to the southern harbour, its contribution to neighbouring subestuaries, sediment yield from the subcatchment (t/y and t/ha/yr), the landuse, soil and slope characteristics, and various mitigation options and opportunity to do them and their effect.

SUBCATCHMENT: Matakana 1 (101-MKE)

Area (km^2) 14.1

Adjacent subestuary Hunters Creek (19-HCK)

Fine sediment fate

Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	42%	
Hunters Creek (19-HCK)	57%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		17th (smallest)

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	63	0.04
SmartGrowth landuse / climate change (S3)	78	0.06

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	0.9	0.9
Exotic forest	55.7	55.6
Urban and roads	0.9	1.1
Urban earthworks	0.0	0.0
Orchard and cropland	11.9	11.9
Pasture	21.5	21.4
Other	9.1	9.1

Other relevant information

Soils. Podzols, allophanics, and sand soils. All well-drained.
Small slopes.
Relatively low rainfall zone.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

LOW

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Not applicable
Pine plantation in steeper or erosion-prone pasture areas	Not applicable
Riparian planting	Not applicable
Enhanced floodplain deposition	Not applicable
Forestry controls	Little effect as flat well-drained.
Urban earthworks controls	Not applicable

SUBCATCHMENT: Mount Maunganui (102-MMI)

Area (km^2)	13.0	
Adjacent subestuary	(6-WPB) Waipu Bay	
Fine sediment fate		
	Proportion of fine-sediment runoff	
Ocean	87%	
(6-WPB) Waipu Bay	11%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		13th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	391	0.30
SmartGrowth landuse / climate change (S3)	438	0.30

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	0.8	0.8
Exotic forest	0.0	0.0
Urban and roads	76.4	76.4
Urban earthworks	0.0	0.0
Orchard and cropland	5.4	5.4
Pasture	15.9	15.9
Other	1.5	1.5

Other relevant information

Soils are poozols and allophanics.
Largely urban, and no proposed urban exapansion.
Relatively low rainfall zone.
32% of load entering streams is from steep pasture (>20 degrees). 0.74% of catchment is steep pasture (Mt Maunganui).

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

LOW

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Opportunity on Mt Maunganui, but little effect as loads likely to leave harbour.
Pine plantation in steeper or erosion-prone pasture areas	Opportunity on Mt Maunganui, but little effect as loads likely to leave harbour.
Riparian planting	Little opportunity or effect.
Enhanced floodplain deposition	No opportunities.
Forestry controls	Not applicable.
Urban earthworks controls	Not applicabe (no earthworks).

SUBCATCHMENT: Papamoa (103-PAP)

Area (km^2)	11.8	
Adjacent subestuary	(1-SPW) Speedway	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	15%	
(1-SPW) Speedway	82%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		14th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	329	0.28
SmartGrowth landuse / climate change (S3)	396	0.34

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	1.3	0.9
Exotic forest	1.0	1.0
Urban and roads	26.3	39.6
Urban earthworks	1.4	0.0
Orchard and cropland	10.3	10.0
Pasture	55.6	44.4
Other	4.1	4.1

Other relevant information

Soils: Variety of soils. Some pasture on gley soils.

Low slopes and relatively low rain, leading to low yields.

Some urbanisation currently, but this is planned to reduce to near zero in the near future.

37% of load from steep pasture (>20 degrees) (Mangatawa). 1.6% of catchment is in steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Opportunities on Mangatawa. Will reduce load from the catchment, but not effective at reducing sediment deposition.
Pine plantation in steeper or erosion-prone pasture areas	Little opportunity
Riparian planting	Little opportunity
Enhanced floodplain deposition	Little opportunity
Forestry controls	Not applicable
Urban earthworks controls	Maintain current controls. Little effect of further controls (most of planned area already urbanised, low slopes, little contribution).

SUBCATCHMENT: Waitao (104-WTO)

Area (km^2)	43.3	
Adjacent subestuary	(2-RNC) Rangataua Bay	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	67%	
(2-RNC) Rangataua Bay	17%	
(1-SPW) Speedway	10%	
(3-WEL) Welcome Bay	6%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		4th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	8029	1.9
SmartGrowth landuse / climate change (S3)	9839	2.3

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	35.9	35.9
Exotic forest	17.5	17.5
Urban and roads	2.0	3.3
Urban earthworks	0.1	0.0
Orchard and cropland	4.0	4.0
Pasture	38.4	37.3
Other	2.1	2.0

Other relevant information

Soils predominantly allophanics, with podzols in upper areas.
Pasture in lower catchment and some mid catchment
Pines in mid catchment
Native bush in upper catchment
Kaitemako quarry in catchment, which has recently had improvements in erosion management. Potentially a significant sediment source.
An active catchment care group.
Steep slopes (>20 degrees) in a considerable proportion of the catchment. Much of this is covered with woody vegetation, but 5.9% of the catchment has steep pasture such as to the west of the upper Waitao.

High rain in the upper catchment.
Surman report notes silting and channel congestion, moderate bank erosion in the Waitao stream.
Small amount of urbanisation in the lower part of the catchments, resulting in a slight increase in sediment yield.

27% of load from steep pasture (>20 degrees). 5.9 % of catchment is in steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

HIGH

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Some remaining opportunities, effective.
Pine plantation in steeper or erosion-prone pasture areas	Some remaining opportunities, effective.
Riparian planting	Opportunities for bank erosion controls. Effectiveness uncertain.
Enhanced floodplain deposition	Some opportunities about 3 km from coast, potentially effective but need to avoid flooding of Waitao Rd.
Forestry controls	Some steep forest areas to be harvested - careful forestry desirable.
Urban earthworks controls	Little effect as not much urbanisation.
Control sediment from quarry	Model shows high yields from these areas Should check this with a more detailed analysis and measurement

SUBCATCHMENT: Kaitemako (105-KMK)

Area (km^2)	19.9	
Adjacent subestuary	(3-WEL) Welcome Bay	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	23%	
(3-WEL) Welcome Bay	71%	
(2-RNC) Rangataua Bay	3%	
(1-SPW) Speedway	2%	
(6-WPB) Waipu Bay	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		10th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	1989	1.0
SmartGrowth landuse / climate change (S3)	2451	1.2

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	10.9	7.6
Exotic forest	2.1	1.6
Urban and roads	20.6	42.7
Urban earthworks	1.2	0.0
Orchard and cropland	3.8	2.7
Pasture	61.2	45.2
Other	0.2	0.2

Other relevant information

Soils: Allophanics
Pasture in large part of catchment, mostly in rolling or strongly rolling terrain
Slopes mostly rolling to strongly rolling
Surman report notes little bank erosion, there are vegetated floodplains.
Considerable urbanisation in the catchment
30% of load from steep pasture (>20 degrees). 5.8% of catchment is in steep pasture.
Considerable gully and stream planting already done.
Rain up to 2 m/y.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

HIGH

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Some remaining opportunities, significant effect.
Pine plantation	Opportunities in upper catchment, significant effect.
Riparian planting	Little effect on bank erosion as bank erosion is not serious in this catchment.
Enhanced floodplain deposition	No good opportunities due to land-use conflicts or topography.
Forestry controls	Not applicable
Urban earthworks controls	Retain good controls. Further controls not effective as a small proportion of load (<1%).

SUBCATCHMENT: Waimapu (106-WMP)

Area (km^2)	118.2	
Adjacent subestuary	(4-WMA) Waimapu	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	42%	
(4-WMA) Waimapu	7%	
(3-WEL) Welcome Bay	5%	
(1-SPW) Speedway	4%	
(2-RNC) Rangataua Bay	2%	
(6-WPB) Waipu Bay	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		2nd

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	16183	1.4
SmartGrowth landuse / climate change (S3)	19131	1.6

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	33.3	32.6
Exotic forest	6.6	6.4
Urban and roads	11.7	18.1
Urban earthworks	0.2	0.2
Orchard and cropland	5.1	3.5
Pasture	42.6	38.7
Other	0.6	0.6

Other relevant information

Soils: Orthic Allophanic in about 2/3 of catchment, pumice in upper 1/3 of catchment.

Considerable current urban fraction and future urbanisation.

Native bush in upper reaches and in stream gullies.

Slopes from undulating to steep. Some steep pasture areas (>20 degrees) with pasture, predominantly in the east of the catchment.

High rain (>2m/year) in upper catchment.

A large part of the main stem is vegetated, with gorges or confined channels, but there are still areas of grazed stream banks. Surman report notes bank slumping in the lower Waiorohi stream, less bank erosion in the Waimapu.

Predicted yields are higher (>3t/ha/year) in the mid and upper parts of the Waimapu Stream catchment due to steep pasture.

27% of load from steep pasture (>20 degrees). 3.4% of catchment is in steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

HIGH

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Considerable opportunities in Waimapu Stream catchment. Significant effect.
Pine plantation in steeper or erosion-prone pasture areas	Considerable opportunities in Waimapu Stream catchment. Significant effect.
Riparian planting	Some further opportunities for retirement, especially in the Waiorohi. Contribution to sediment sources probably not major.
Enhanced floodplain deposition	Not much opportunity in the Waimapu due to land-use conflicts in lower catchment and topography in upper catchment. Some opportunity in the Wairohi.
Forestry controls	Little opportunity, as current forests are not in particularly steep areas.
Urban earthworks controls	Maintain good erosion controls, but earthworks make only a minor contribution to load.

SUBCATCHMENT: Kopurererua (107-KOP)

Area (km^2)	78.8	
Adjacent subestuary	(7-WKE) Waikareao	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	80%	
(7-WKE) Waikareao	19%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		3rd

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	7943	1.0
SmartGrowth landuse / climate change (S3)	9418	1.2

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	32.7	32.2
Exotic forest	5.4	4.5
Urban and roads	15.7	31.4
Urban earthworks	0.6	0.0
Orchard and cropland	5.5	2.8
Pasture	39.9	28.9
Other	0.2	0.1

Other relevant information

Soils : Orthic allophanics in lower 2/3 of catchment, Pumice in upper catchment.
Steep slopes in gullies, but these are generally vegetated with bush cover.
Pasture is predominantly on the flatter areas
Considerable proportion of urban area, and current and ongoing urbanisation.
Surman report notes some bank erosion in meandering sections in mid reaches, although banks were low so not much sediment involved. Lower reaches straightened with little erosion.
22% of load from steep pasture (>20 degrees). 2.1% of catchment is in steep pasture.
High rain in upper catchment

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate effect. Considerable proportion of pasture is in flatter areas. Some opportunities in southern catchment.
Pine plantation in steeper or erosion-prone pasture areas	Moderate effect. Considerable proportion of pasture is in flatter areas. Some opportunities in southern
Riparian planting	There are a few opportunities in the mid reaches, overall contribution uncertain but probably minor.
Enhanced floodplain deposition	Potential for flood deposition in lower reaches, but this seems to be in conflict with proposed urbanisation.
Forestry controls	Minor contribution.
Urban earthworks controls	Maintain good erosion controls, but earthworks make only a minor contribution to load.

SUBCATCHMENT: Wairoa (108-WAR)

Area (km^2)	465.3	
Adjacent subestuary	(8-WAR) Mouth of Wairoa River	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	95%	
(7-WKE) Waikareao	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		1st (largest)

Fine sediment from subcatchment 108 is dispersed widely throughout the central reaches of southern Tauranga Harbour, between the (southern) harbour mouth and Omokoroa Point. Omokoroa Point evidently acts as something of a barrier to fine sediment from southern sources passing into the northern reaches of the harbour. Fine sediment from the Wairoa River is also dispersed into the southern part of the harbour, spreading around the Tauranga City peninsula and as far afield as Waikareao estuary (7–WKE) and Waipu Bay (6–WPB). Widespread dispersal of fine sediment from subcatchment 108 is consistent with the central location of the Wairoa River mouth, and the river's high freshwater discharge.

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	49630	1.1
SmartGrowth landuse / climate change (S3)	59341	1.3

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	57.2	57.2
Exotic forest	14.3	14.3
Urban and roads	1.4	2.4
Urban earthworks	0.1	0.0
Orchard and cropland	2.2	2.0
Pasture	24.4	23.7
Other	0.4	0.4

Other relevant information

Soils: Orthic Allophanics in lower catchment, Orthic Podzols in upper catchment.
Pines in upper catchment, generally on low to moderate slopes.
Native bush in upper catchment and gully areas.
Steep (>20 degrees) slopes in considerable proportion of the catchment, predominantly in the western half and in stream gullies. Steep areas generally have tree cover, but there are some pasture areas with steep pasture.
High rain in south and west of catchment.
Surman report notes that lower Wairoa River is generally stable. Omanawa has significant lengths of exposed banks. Ohourere stable (rock).

Surman notes that Jensen's Gully in Omanawa Stream catchment caused significant sediment source, and has a detention dam.

Small fraction of urbanisation.
17% of load entering streams is from steep pasture (>20 degrees). 1.7% of catchment is steep pasture.
Water from large part of upper catchment is diverted through hydro impoundments (Lake McLaren) but these will not trap a major proportion of fine sediment as Lake McLaren is run-of-the-river.

LRI notes moderate slips in Ohourere Stream catchment and gullied areas of upper Omanawa and Mangapapa.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment
LOW

Mitigation options	Opportunity and effect
Retirement or further conservation planting in erosion-prone pasture areas	Some opportunities, especially to the west of the upper Wairoa River and upper catchment around SH29.
Pine plantation in steeper or erosion-prone pasture areas	Some opportunities, especially to the west of the upper Wairoa River and upper catchment around SH29.
Riparian planting	Few opportunities. Most of network vegetated except for some headwater pasture areas. Lower Wairoa stable. Some opportunity in lower Omanawa.
Enhanced floodplain deposition	Little opportunity Wairoa. Some possiblities in lower Omanawa.
Forestry controls	Little effect as most forestry on mild to moderate slopes.
Urban earthworks controls	Little effect as litte urbanisation.

SUBCATCHMENT: Oturu (109-OTU)

Area (km^2)	11.6	
Adjacent subestuary	(9-WKA) Waikaraka	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	26%	
(9-WKA) Waikaraka	73%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		12th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	455	0.39
SmartGrowth landuse / climate change (S3)	561	0.48

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	14.4	14.3
Exotic forest	1.3	1.3
Urban and roads	8.4	8.5
Urban earthworks	0.0	0.0
Orchard and cropland	30.8	30.8
Pasture	44.3	44.3
Other	0.8	0.8

Other relevant information

Soils: Allophanics

Slopes. Mostly small slopes, but some hills in southern catchment which have mostly native vegetation but also some pasture.

Relatively low rain zone.

No urbanisation planned.

18% of load entering streams is from steep pasture (>20 degrees). 1.3% of catchment is steep pasture.

Old Te Puna quarry in catchment, mostly re-vegetated.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Some opportunities of moderate effectiveness in upper catchment.
Pine plantation in steeper or erosion-prone pasture areas	Little opportunitiy as areas small and fragmented.
Riparian planting	Little opportunity. Streams mostly have protection
Enhanced floodplain deposition	No opportunity. Terrain and land-use not appropriate.
Forestry controls	Not applicable
Urban earthworks controls	Not applicable.
Cropping controls	Little opportunity (largely ochards), probably little effect.

SUBCATCHMENT: Te Puna (110-TPU)

Area (km^2)	28
Adjacent subestuary	(26-TPI) Te Puna (inner)

Fine sediment fate

Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	26%	
(26-TPI) Te Puna (inner)	67%	
(10-TPU) Te Puna	6%	
(20-MGI) Mangawhai Bay (inner)	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		8th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	4292	1.5
SmartGrowth landuse / climate change (S3)	5201	1.9

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	16.6	16.6
Exotic forest	7.8	7.8
Urban and roads	4.3	4.3
Urban earthworks	0.0	0.0
Orchard and cropland	12.5	12.5
Pasture	57.7	57.7
Other	1.1	1.1

Other relevant information

Soils predominantly allophanics.

Some steep areas (>20 degrees), which have mostly native vegetation but also some steep pasture.

High rain in upper half of catchment. These areas have pasture land use.

Surman report notes stop-banking in lower catchment, stable rock bed and banks for much of the stream and little erosion.

20% of load entering streams is from steep pasture (>20 degrees). 2.7% of catchment is steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate opportunity and effect.
Pine plantation in steeper or erosion-prone pasture areas	Moderate opportunity and effect.
Riparian planting	Little opportunity as streams are largely vegetated and stable.
Enhanced floodplain deposition	Little opportunity (stop-banked).
Forestry controls	Not applicable.
Urban earthworks controls	Not applicable.
Cropping controls	Little opportunity.

SUBCATCHMENT: Mangawhai (111-MGW)

Area (km^2)	9.6	
Adjacent subestuary	(20-MGI) Mangawhai Bay (inner)	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	41%	
(20-MGI) Mangawhai Bay (inner)	53%	
(11-MGO) Mangawhai Bay (outer)	6%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		11th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	1198	1.2
SmartGrowth landuse / climate change (S3)	1428	1.5

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	4.3	4.0
Exotic forest	2.0	0.7
Urban and roads	15.3	37.1
Urban earthworks	0.2	0.0
Orchard and cropland	18.0	15.6
Pasture	59.6	42.2
Other	0.7	0.4

Other relevant information

Orthic allophanic soils.
Generally undulating to rolling, but small areas of moderately steep slopes.
Rain 1500 to 1900 mm/year.
Surman report notes low yield measured previously by Murray Hicks. Streams not surveyed but seem to have stock access.
Considerable urbanisation planned on Omokoroa Peninsula.

23% of load entering streams is from steep pasture (>20 degrees). 2.5% of catchment is steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate opportunity, moderate effect.
Pine plantation in steeper or erosion-prone pasture areas	Moderate opportunity, moderate effect.
Riparian planting	Some opportunities in semi-confined channels in mid catchment as much of the riparian area is grazed, but probably need to maintain flood conveyance in lower reaches. Effect uncertain.
Enhanced floodplain deposition	Little opportunity due to topograhy and land-use limitations.
Forestry controls	Not applicable.
Urban earthworks controls	Earthworks contribution minor with current controls.

SUBCATCHMENT: Waipapa (112-WAI)

Area (km^2)	36.8	
Adjacent subestuary	(12-WAI) Mouth of Waipapa River	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	53%	
(12-WAI) Mouth of Waipapa River	45%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		6th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	4731	1.3
SmartGrowth landuse / climate change (S3)	5672	1.5

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	33.4	33.0
Exotic forest	4.3	4.1
Urban and roads	3.3	12.4
Urban earthworks	0.0	0.0
Orchard and cropland	10.9	6.2
Pasture	47.7	44.1
Other	0.4	0.3

Other relevant information

Allophanic soils in lower cathment, podzols in upper catchment.

Steep slopes in stream gullies. Some steep hills also in lower half of catchment with pasture.

High rainfall in upper catchment. Some of this has pasture land cover. Medium rain in the rest of the catchment.

Surman report notes significant erosion for short stretches, usually where willows have caused blockages.

Some urbanisation on Omokoroa Peninsula.

22.1% of load entering streams is from steep pasture (>20 degrees). 2.6% of catchment is steep pasture.

Some areas of moderate slipping noted in LRI.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate opportunities and effect.
Pine plantation in steeper or erosion-prone pasture areas	Moderate opportunities and effect.
Riparian planting	Some opportunities, probably minor effect.
Enhanced floodplain deposition	Little opportunity.
Forestry controls	Not applicable.
Urban earthworks controls	Earthworks contribution minor with current controls.

SUBCATCHMENT: Apata (113-APA)

Area (km^2)	12.4
Adjacent subestuary	(13-PAH) Pahoia Beach Road

Fine sediment fate

Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	41%	
(13-PAH) Pahoia Beach Road	54%	
(14-WNR) Mouth of Wainui River	4%	
(15-AGR) Mouth of Aongatete River	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		9th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	2967	2.4
SmartGrowth landuse / climate change (S3)	3578	2.9

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	2.8	2.8
Exotic forest	4.6	4.6
Urban and roads	4.6	4.8
Urban earthworks	0.0	0.0
Orchard and cropland	19.7	19.7
Pasture	66.4	66.3
Other	1.8	1.8

Other relevant information

Allophanic soils.

Some steep slopes in hill pasture areas.

Medium rainfall zone.

Surman report notes generally stable or well-vegetated streams, but occasional grazed streambanks and stream erosion.

No urbanistation.

21% of load entering streams is from steep pasture (>20 degrees). 4.8% of catchment is steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate to large opportunities and effect.
Pine plantation in steeper or erosion-prone pasture areas	Moderate to large opportunities and effect.
Riparian planting	Some opportunities, probably minor effect.
Enhanced floodplain deposition	Little opportunity.
Forestry controls	Not applicable.
Urban earthworks controls	Not applicable.

SUBCATCHMENT: Wainui (114-WNR)

Area (km^2)	35.2	
Adjacent subestuary	(14-WNR) Mouth of Wainui River	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	32%	
(14-WNR) Mouth of Wainui River	67%	
(15-AGR) Mouth of Aongatete River	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		5th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	4893	1.4
SmartGrowth landuse / climate change (S3)	5840	1.7

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	56.8	56.8
Exotic forest	1.0	1.0
Urban and roads	2.1	2.1
Urban earthworks	0.0	0.0
Orchard and cropland	4.2	4.2
Pasture	35.3	35.3
Other	0.5	0.5

Other relevant information

Allophanic soils in lower catchment, podzols in upper catchment

Steep slopes in stream gullies. Some steep hills also in lower half of catchment with pasture.

High rain in upper catchment, but this has bush cover. Medium rain in rest of catchment, with pasture cover.

Surman report notes stream mostly has vegetation or is stable, with stream erosion not an issue.

No urbanisation.

23.7% of load entering streams is from steep pasture (>20 degrees). 2.6% of catchment is steep pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate opportunities and effect.
Pine plantation in steeper or erosion-prone pasture areas	Moderate opportunities and effect.
Riparian planting	Little remaining opportunity.
Enhanced floodplain deposition	No opportunity
Forestry controls	Not applicable
Urban earthworks controls	Not applicable

SUBCATCHMENT: Aongatete (115-AGR)

Area (km^2)	78.5	
Adjacent subestuary	(15-AGR) Mouth of Aongatete River	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	40%	
(15-AGR) Mouth of Aongatete River	60%	
(14-WNR) Mouth of Wainui River	1%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		7th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	4750	0.6
SmartGrowth landuse / climate change (S3)	5835	0.7

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	58.5	58.5
Exotic forest	1.4	1.4
Urban and roads	2.0	2.1
Urban earthworks	0.0	0.0
Orchard and cropland	6.3	6.3
Pasture	31.5	31.5
Other	0.3	0.3

Other relevant information

Allophanic soils in lower cathment, podzols in upper catchment.

Steep slopes in stream gullies. Some steep hills also in lower half of catchment with pasture.

High rain in uppermost catchment, but this has bush cover. Medium rain in rest of catchment, with pasture cover.

Surman report notes stopbanking and erosion control in lower reaches.

No urbanisation.

20.3% of load entering streams is from steep pasture (>20 degrees). 1.9% of catchment is steep pasture.

Some debris avalanche areas noted in upper bush areas in LRI. Also some slip areas of moderate erosion risk in pasture.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

MEDIUM

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Moderate opportunities and effect.
Pine plantation in steeper or erosion-prone pasture areas	Moderate opportunities and effect.
Riparian planting	Few further opportunities.
Enhanced floodplain deposition	No opportunities.
Forestry controls	Not applicable.
Urban earthworks controls	Not applicable.

SUBCATCHMENT: Bellevue (116-MAT)

Area around Matua embayment near mouth of Wairoa.

Area (km^2)	9.5	
Adjacent subestuary	(25-MAT) Matua	
Fine sediment fate		
Where fine sediment ends up	*Proportion of fine-sediment runoff*	
Ocean	64%	
(25-MAT) Matua	37%	
Others	<1%	
Ranking of subcatchment by total sediment runoff to harbour		16th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	217	0.2
SmartGrowth landuse / climate change (S3)	257	0.3

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	1.2	0.8
Exotic forest	0.8	0.6
Urban and roads	60.9	90.5
Urban earthworks	2.4	0.0
Orchard and cropland	5.3	0.8
Pasture	25.2	4.1
Other	4.2	3.2

Other relevant information

Mixed soils. Some urbanisation into Acid Gley soils.
Largely urban catchment currently, and nearly all of the catchment will be urbanised.
Small slopes.
Low rainfall zone.
Little of the deposition in the Matua subestuary comes from the Bellevue subcatchment.
Some proposed earthworks are on erodible soils, but the slopes are small so conventional controls should be adequate.
Approximately 0.15% of load is from urban earthworks in 2001.

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

LOW

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Not applicable
Pine plantation in steeper or erosion-prone pasture areas	Not applicable
Riparian planting	Opportunity but little effect.
Enhanced floodplain deposition	No opportunity
Forestry controls	Not applicable
Urban earthworks controls	Maintain controls on earthworks. Pay particular attention to gley soils.

SUBCATCHMENT: Matakana 2 (117-MKW)

Western Matakana, discharges to Matakana Island subestuary

Area (km^2)	7.5
Adjacent subestuary	(117-MKI) Matakana Island

Fine sediment fate

Where fine sediment ends up	*Proportion of fine-sediment runoff*
Ocean	88%
(17-MKI) Matakana Island	5%
(11-MGO) Mangawhai Bay (outer)	1%
(14-WNR) Mouth of Wainui River	1%
(15-AGR) Mouth of Aongatete River	1%
(18-RGI) Rangiwaea Island	1%
(19-HCK) Hunters Creek	1%
(20-MGI) Mangawhai Bay (inner)	1%
Others	<1%

Ranking of subcatchment by total sediment runoff to harbour 15th

Sediment yield (average 2001-2051)	Load (t/y)	Yield (t/ha/y)
SmartGrowth landuse / present-day weather (S2)	316	0.4
SmartGrowth landuse / climate change (S3)	390	0.5

Landuse breakdown (%)	2001	2041
Bush, scrub and native forest	14.1	14.1
Exotic forest	2.7	2.7
Urban and roads	1.2	1.2
Urban earthworks	0.0	0.0
Orchard and cropland	10.1	10.1
Pasture	70.2	70.2
Other	1.7	1.7

Other relevant information

Soils predominantly allophanics
Undulating slopes
Low rainfall zone

Overall potential for mitigation (HIGH, MEDIUM, LOW) of sediment runoff from catchment

LOW

Mitigation options	**Opportunity and effect**
Retirement or further conservation planting in erosion-prone pasture areas	Few opportunities, minor effect.
Pine plantation in steeper or erosion-prone pasture areas	Few opportunities, minor effect.
Riparian planting	Not applicable
Enhanced floodplain deposition	Not applicable
Forestry controls	Not applicable
Urban earthworks controls	Not applicable