Ministry for Primary Industries
Manatū Ahu Matua

Waiapu River Catchment Study

Final Report

MPI Technical Paper No: 2012/32

Prepared by SCION

ISBN No: 978-0-478-40446-3 (online)
ISSN No: 2253-3923 (online)

November 2012

New Zealand Government

Growing and Protecting New Zealand

Report Information Sheet

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Client:	Ministry of Agriculture and Forestry
Client Contract No:	15201
Sidney output number:	48874
Reviewed by:	Brenda Baillie
Signed off by:	Peter Clinton
Date:	13 June 2012

Report reference:
Scion. (2012). *Waiapu River Catchment Study –Final Report*. Scion Confidential Client Report No. 15201. Rotorua, New Zealand: Scion.

Chapter references:

Chapter 1:
Jones, H. S., Barnard, T. D., Barry, L., Bloomberg, M., Fitzgerald, G., Garrett, L. G., Harrison, D., Moore, D. J., Morgenroth, J., Page, M. J., Peacock, D. H., Porou, T., & Rosser, B. J. (2012). General introduction. In Scion. *Waiapu River Catchment Study –Final Report* (pp. 1-2). Scion Confidential Client Report No. 15201. Rotorua, New Zealand: Scion.

Chapter 2:
Rosser, B. J., Page, M. J., & Peacock, D. H. (2012). Literature review – a review of the geophysical & land use aspects of the erosion problem in the Waiapu catchment. In Scion. *Waiapu River Catchment Study –Final Report* (pp. 3-102). Scion Confidential Client Report No. 15201. Rotorua, New Zealand: Scion.

Chapter 3:
Barnard, T. D., Porou, T., Moore, D. J., Garrett, L. G., & Barry, L. (2012). Literature review & kōrero – impacts of land use change & erosion on Ngāti Porou in the Waiapu catchment. In Scion. *Waiapu River Catchment Study –Final Report* (pp. 103-137). Scion Confidential Client Report No. 15201. Rotorua, New Zealand: Scion.

Chapter 4:
Rosser, B. J., Page, M. J., Peacock, D. H., Bloomberg, M., & Morgenroth, J. (2012). Benchmarking, scope assessment, & critical evaluation – geophysical aspects. In Scion. *Waiapu River Catchment Study –Final Report* (pp. 138-172). Scion Confidential Client Report No. 15201. Rotorua, New Zealand: Scion.

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Chapter 7:
Jones, H.S., Bloomberg, M., Page, M.J., Rosser, B.J., Porou, T., Barnard, T., Peacock, D.H., & Moore, D. (2012). Toward a desired state for the Waiapu River & catchment. In Scion. *Waiapu River Catchment Study –Final Report* (pp. 260-293). Scion Confidential Client Report No. 15201. Rotorua, New Zealand: Scion.

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Executive summary

This report presents the work undertaken on the Waiapu River Catchment Study, the purpose of which was to investigate the geophysical, social, cultural, and economic dimensions of the erosion problem in the Waiapu River catchment in order to inform future policy decisions with respect to the catchment in the context of the Deed of Settlement between Ngāti Porou and the Crown. The report includes:

- An outline of existing knowledge related to the (i) geophysical and land use aspects and (ii) social, cultural, and economic aspects of erosion and land use change within the Waiapu River catchment and the wider East Coast region.
- Identification of gaps in the existing knowledge apparent to the research team, and recommendations for addressing any gaps identified.
- A description of a baseline from which future progress in the Waiapu catchment may be measured (benchmarking) for the (i) geophysical and land use aspects and (ii) social, cultural, and economic aspects of erosion against the values of Ngāti Porou for the catchment and well-being of the people.
- An outline of the project team's interpretation of a desired state for Ngāti Porou and consideration of possible options for addressing the erosion problem.
- Assessments of the scope (size and scale) of the erosion problem in the catchment and critical evaluations of the effectiveness of erosion mitigation measures for the (i) geophysical aspects and (ii) social, cultural, and economic aspects of erosion.

Main findings

Outline of existing knowledge

Geophysical & land use aspects

The key points to emerge from the literature relating to the geophysical and land use aspects of the erosion problem in the catchment are:

- The Waiapu catchment is located in a dynamic tectonic and climatic setting. Recent and extensive deforestation has exacerbated the high natural rates of erosion and sedimentation. The response to deforestation has been rapid and pronounced.
- Research to date has provided some insight into landscape controls on sediment generation and transfer in the Waiapu catchment following deforestation. However, much of the research has been focused on gully erosion.

- Extensive gully erosion commenced within one or two decades, and now accounts for 49% of the annual suspended sediment yield of 35 Mt, which is more than twice that of the adjacent Waipaoa River, the next highest yielding New Zealand River, and nearly ten times that of the Manawatu River. Similarly, channel responses to sudden fluctuations in sediment supply have been rapid with channels aggrading, and particularly in the lower reaches, widening markedly.
- Recent research also shows that land use/vegetation change is the most effective method of controlling erosion. Modelling indicates that planting all East Coast Forestry Project (ECFP) ‗target land' by 2020 is more effective than planting all Land Overlay 3A (LO3A) land, and the earlier this is achieved the greater the reduction in gully-derived sediment yield. However, sediment yield from gullies will still increase due to unplanted gullies, unstablised gullies, and new gullies on untreated areas outside the ECFP target land.
- The rates of erosion and relative sediment contribution by processes other than gully erosion (i.e. landslide, earthflow, sheetwash, streambank erosion, and river bed degradation) under different land uses and land management practices represents a significant research gap. These other processes account for 51% of the sediment yield.
- The gaps in existing knowledge limit our ability to identify the amount, mix, and spatial distribution of erosion mitigation measures (afforestation, reversion, and wide-spaced tree planting) required to improve geophysical conditions sufficient to achieve a 'desired state‗ as identified by Ngāti Porou. More specifically, how much afforestation, reversion, and wide-spaced tree planting is required to affect a switch from aggradation to incision and how long it will take for the effects to manifest in the main stem of the Waiapu River are unanswered questions.

Social, cultural, & economic aspects

The key points to emerge from the literature relating to the social, cultural, and economic aspects (impacts on Ngāti Porou, in particular) of the erosion problem in the catchment are:

- The Waiapu catchment is of great spiritual, cultural, and economic significance to Ngāti Porou and the health of the catchment extends much further than the physical elements of the landscape.
- Many Ngāti Porou have had concerns about commercial forestry as a means to control erosion.
- The disestablishment of the New Zealand Forest Service and subsequent sale of forests had major impacts on Ngāti Porou communities and their view of Governmental agencies.
- Concerns that families and communities have become socially dislocated.

- Many Ngāti Porou seek mana motuhake over the river and catchment, and its restoration or healing. This is supported by a view that the catchment needs a strategy that fully represents the aspirations and values of the community.

Benchmarking, scope assessment, & critical evaluation

Geophysical & land use aspects

- The geophysical state of the catchment has been described at 1840, 1969, 1988, and 2008 to enable assessment of the size and scale of the erosion problem going forward, and the impacts of past land use changes and efforts and policies to address the erosion problem.
- In 1840, 88% of the catchment was in primary indigenous forest, with the remainder mainly in scrub and secondary forest. In 2008, vegetation cover was as follows: indigenous forest and scrub 35%, planted forest 25%, grassland 35%, and other 5%.
- Gullies, which began to develop following deforestation (1890-1920), now account for 49% of the catchment sediment yield. While the number of gullies has decreased from 1,468 in 1957 to 683 in 2008, sediment yield has risen from 13.49 Mt in 1957 to 23.97 Mt in 2008 due to the increase in size of unplanted gullies and the initiation of new gullies in areas of gully prone land that remain untreated.
- The remaining 51% of the catchment sediment yield is derived from other erosion processes (i.e. landslide, earthflow, sheetwash, streambank erosion, and river bed degradation). The contribution of these processes to the sediment yield is unknown.
- River cross-section data show that while some headwater streams where afforestation has occurred have begun to incise, larger rivers are still aggrading and their channels are continuing to widen.
- While channel incision in response to afforestation has been rapid (decades) in headwater catchments, the rate at which incision will proceed downstream is unknown, and depends on the amount and timing of future afforestation and storm events.
- Afforestation, reversion, and wide-spaced planted trees are all effective in reducing erosion under appropriate conditions.
- The scale of the erosion problem in the catchment can be represented by the area of untreated land with Potential Erosion Severity (PES) of 4 or 5, plus the area of gully-prone land without effective tree cover that is not included within the area of land with a PES of 4 or 5. This area was estimated to be up to a maximum of about 28,000 ha as at 2008.
- Land with severe potential severity (PES 3) is also likely to require intensive soil conservation measures to prevent significant erosion on this land.

- The gully complex model (Herzig et al., 2011) shows that afforestation has reduced sediment yields by 17% from what it would have been without any afforestation.
- Despite the establishment of 54,000 ha of forest, gully-derived sediment yield has increased by 78% between 1957 and 2008 because of the growth of untreated gullies and the establishment of new gullies.
- The gully complex model suggests that if all gullies were to be afforested by 2020, the sediment yield from gullies could be reduced by half (from 22 Mt/yr to 11 Mt/yr) by 2050, but if afforestation efforts were terminated today, and new gullies were also left untreated, the sediment yield from gullies would double (to 45 Mt/yr) by 2050.
- The gully complex model indicates that a larger area than that identified by the ECFP or other programmes requires treatment to reduce gully-derived sediment yields.
- It is estimated that up to about 28,000 ha of the land remaining under grassland in the Waiapu catchment will need to be treated to attempt to address the erosion problem and reduce sediment yields.
- Natural climate variability, climate change, and the impact of another Cyclone Bola or an earthquake are identified as uncertainties that may affect progress towards the desired state for the catchment.
- A geospatial (map-based) description of current land cover, land tenure, and erosion in the Waiapu catchment is provided and used to gauge the effectiveness of policies intended to control erosion.
- The effectiveness of policies to control erosion can be gauged by the extent of large-scale afforestation or regeneration of natural forest and scrub from 1969 to the present day. In addition, geospatial analysis of target ECFP land and LO3A land shows remaining unplanted ‘target land‗for afforestation.
- Highly erodible land with a PES of 4 or 5 makes up 43% of the Waiapu catchment. However, about two-thirds of the land with PES of 4 or 5 is already under natural or planted forest cover, with a small area in grassland with woody biomass. About 19,000 ha remain in pasture, and are therefore at risk of very severe or extreme erosion.
- Only about 3% of the catchment area has very severe or extreme (4 or 5) present erosion and three quarters of this land is under natural or planted forest cover.
- Both the ECFP and the Gisborne District Council‘s (GDC) Combined Regional Land and District Plan identify their target areas as LUC units 7e18, 19 and 21-25, and 8e2-9. However, the ECFP area is based on the NZ Land Resource Inventory, mapped at 1:50,000 scale. The GDC mapping is based on property-scale mapping (for reasons of enforcement and farm plan development), which leads to a smaller area of target land compared with the NZLRI mapping.

- Based on the analysis undertaken in this study, a total of 40% of the ECFP eligible LUC classes in the Waiapu catchment are already in natural forest, leaving 41,003 ha currently under other land covers. Of this 22,162 ha have been planted in exotic forest. Data supplied by the Ministry of Agriculture and Forestry (MAF) indicate that there are about 13,526 ha of ECFP target land yet to be treated (i.e. currently under grassland). Areas planted under the ECFP also include a significant portion of non-target land (14,466 ha).
- The GDC‗s LO3A area is about half the size of the eligible ECFP area (with natural forest excluded). LO3A land differs from ECFP target land in that ECFP target land incorporates more gullies and involves planting of a greater portion of the catchment surrounding each gully. About 65% percent is either in planted forest or natural forest. This leaves 7,770 ha of grassland that GDC require to be treated.
- About 38% of the highly erodible land (PES 4 and 5) occurs under general title and a further 27% of the highly erodible land in is Māori ownership. However, much of the Crown land area is expected to be returned to Ngāti Porou under the terms of their Treaty settlement with the Crown. Combined Crown and Māori land would account for approximately 40% of the highly erodible land. The Department of Conservation (DoC) land accounts for about 22% of the highly erodible land within the catchment.
- Afforestation of general title land will largely be driven by commercial considerations or mandatory requirements for planting of LO3A land, or both. The uptake of treatment on privately-owned land will be voluntary except in areas where it is required under the Gisborne Combined Regional Land and District Plan (i.e. LO3A). Afforestation of Māori-owned land will likely be subject to a wider set of considerations, and the decision to reforest will probably involve more complex processes.

Social, cultural, & economic aspects

- Together with invited members of Ngāti Porou, we have developed a bi-cultural framework of criteria and indicators which, when taken together, describe a ‗desired state‗ and which may be used to describe key past and current data of relevance, and assess progress toward a desired state in the current environment (including policy and mitigation efforts to date).
- It is acknowledged by the project team that further consultation is required with Ngāti Porou on the indicator set.
- This component of the work drew from a pool of around 30 documents dating back to the 1891 census, but predominantly on a small number of key works most of which were produced within the last ten years and are largely ethnographic in nature.

- Supplementary data on criteria and indicators of a Ngāti Porou ‗desired state' were gathered and compiled specifically for this study in late 2011.
- The literature presents a picture of a fragile landscape with its ability to support the needs and aspirations of Ngāti Porou greatly reduced over a century and a half.
- A socio-economic profile of Ngāti Porou in the Waiapu catchment outlining the state of community wellbeing is presented. According to the 2006 Deprivation Index, the East Coast area (and Gisborne District) is one of the most socio-economically deprived areas in the country. This has been the case since deprivation indices were attempted in the 1980's.
- Within the district, the people of Waiapu catchment, especially those resident in the northern part (i.e. lower end of the river), are among the 10% most deprived people in the nation. In short, the residents of the Waiapu catchment are especially poor by New Zealand standards — both materially and in access to opportunity.
- Prior to Cyclone Bola the Waiapu area was already disadvantaged. The situation was made worse after 1985 (before Cyclone Bola) when the Government corporatised (and later privatised) the New Zealand Forest Service.
- A major strength of this research is that it presents a valuable Ngāti Porou worldview, and also an East Coast perspective on the multiple causes and diverse long-term impacts of erosion on communities and their aspirations.
- A repeated theme in the literature and this chapter of the report is the view expressed by many Ngāti Porou that erosion is not an isolated problem and that integrated approaches are required to tackle the many problems the catchment faces. Future strategies should embrace Ngāti Porou values and aspirations fully.
- Flood, sediment, and erosion damage to stocks and flows of critical natural capital compromises the ability of local people to meet their needs, especially with respect to abundant good quality seasonal food, fresh clean water, and other resources.
- Degradation and loss of natural capital within the catchment is likely to have contributed to on-going rural depopulation and a loss of human and social capital, with associated reduced community functioning, strength, reduced wellbeing, reduced cultural identity and expression, loss of services, and economic marginalisation.
- High levels of social and economic deprivation which are not helped by a degraded landscape and eroded natural capital.
- A dependency and reliance on external intervention to address the problem at the catchment/landscape level.
- An awareness of a reduced connection between the people and the whenua (river, forest, and natural world) and each other, resulting in reduced physical and spiritual wellbeing.

- A loss of general and specialist knowledge of the environment and cultural practices associated with catchment-based livelihoods over time as a result of landscape change and the loss of a traditional resource base.
- A loss of economic development opportunities and options as a result of a degraded landscape.
- Direct damage to houses, infrastructure, and productive land from increasingly frequent and voluminous floods.
- A lack of engagement in catchment management, decision making, and planning is perceived to be preventing the community from pursuing its own vision of a desired state for the Waiapu catchment and hindering community engagement in the resolution of the problem.
- Loss of soil from the Waiapu catchment, as a result of erosion, has reduced the ability of the catchment to meet community needs; consuming resources that may be used to support economic development.
- The present value of lost pasture productivity due to slip erosion is estimated at $415,000 per annum in the Waiapu catchment.
- The value of lost pasture productivity due to surface erosion in the Waiapu catchment is estimated at $440,000 per annum.
- The Waiapu catchment faces many other costs as a result of soil erosion, through damage to infrastructure, insurance costs, recreational loss, and biological degradation. Some can be estimated but further research is needed to determine the full economic impact from soil erosion in the Waiapu.
- An indicative estimate of the total cost to central Government to treat the remaining ECFP land in the Waiapu catchment would be in the region of $24 million.
- The ECFP and LO3A do not have explicit social, economic, and cultural objectives. The number of indicators developed by Ngāti Porou through this research and their breadth in terms of the issues they raise would suggest that the challenges facing the catchment and its people are many and only a very small number of these are being addressed by current efforts.

Toward a desired state for the catchment

- A desired state for the Waiapu River and catchment, as expressed during the consultation with Ngāti Porou undertaken as part of this study, is presented and its key elements summarised.
- The achievability of controlling erosion in the context of a desired state is assessed in relation to (1) improved water quality and river condition, (2) protection and restoration of natural forests, and (3) no further deterioration of the river and catchment.

- In the absence of relevant New Zealand-based information, international examples suggest that restoration of river conditions following woody revegetation may take in the order of multiple decades to a century.
- Mechanisms (e.g. Nga Whenua Rahui) are available for the protection of exiting areas of natural forest. At least in the short-term, large scale artificial re-establishment of natural forests to control erosion is unlikely to be practicable due to issues of supply and cost of nursery-raised seedlings. However, a mixed treatment strategy involving natural regeneration and small-scale planting of key sites could be financially and practically possible.
- Urgent action is required to avoid further deterioration of the river and catchment from its current state, at least with respect to sediment yield from gullies. If no gullies are planted after 2008, the sediment from gullies is predicted (by Herzig et al., 2011) to increase from 22 Mt/yr to 45 Mt/yr by 2050.
- We make comment on possible options to control erosion (involving the revegetation of eroding and erosion-prone land) in order to move toward addressing aspects of a desired state for the catchment. The suggested options are starting-points for further consideration and development of solutions with Ngāti Porou and the local communities.
- From a cultural perspective, it will be essential that models of afforestation and forestry adopted to address the erosion problem include integrated management using matauranga Maori frameworks.
- Recent modelling of gully-derived sediment yield from the catchment between 2008 and 2050 under different afforestation scenarios was undertaken by Herzig et al. (2011). The results of the study provide some useful geophysical context and guidance with respect to the potential effectiveness of some possible options for addressing the erosion problem.
- Afforestation leading to rapid canopy closure is generally expected to be the most effective approach to treating areas of eroding and erosion-prone land within the Waiapu catchment. Therefore, the possible options are discussed in terms of afforestation as the default approach to the treatment of the areas involved although it is recognised that a suitable mix of afforestation, reversion, and wide-spaced tree planting may offer acceptable site-specific solutions.
- The following possible options are suggested:
  - Option One: Afforest all gullies and their associated catchments.
  - Option Two: Afforest all ECFP target land.
  - Option Three: Afforest all ECFP target land plus all gullies and their associated catchments.
  - Option Four: Afforest all Potential Erosion Severity 4 and 5 land.

  - Option Five: Afforest all Potential Erosion Severity 4 and 5 land plus all gullies and their associated catchments.
- Comment on the land use change implications of, and potential issues and opportunities around, the various approaches to the revegetation of eroding and erosion-prone land is made.
- A mix of treatment approaches is possible and could involve:
  - Natural regeneration of indigenous species such as manuka and kanuka, and planting of other indigenous species with high conservation or cultural values on a smaller-scale and on suitable sites.
  - Planting exotic forest, especially on sites where soil and water impacts of harvesting can be managed and harvesting and transport costs do not limit profitability.
  - Wide-spaced tree planting (poles and wands) on sites that can be managed for silvo-pastoralism (trees plus grazing).
- Sediment yields would be expected to remain higher for longer periods of time if treatment options that take longer to achieve canopy closure (e.g. natural reversion), or that will not involve canopy closure at all (e.g. wide-spaced tree planting), are used instead of afforestation.
- The socio-economic and cultural context around the land use change is briefly considered. This included consideration of land tenure of highly erodible land under grassland, some economic implications, potential effects on communities, and cultural aspirations.
- It has been recognised that uptake of ECFP grants has been slow and, as a consequence, the scheme has struggled to achieve significant areas of afforestation, reversion, or wide-spaced tree planting. Possible reasons for the slow uptake of the scheme, as identified in the literature, include:
  - Financial and economic barriers (e.g. bridging finance and comparative returns from pastoral farming).
  - Complexity due to the multiple land ownership of Māori land.
  - Limitations of the scheme (e.g. must establish in year of approval, covenants, restrictive forestry regimes, and compatibility with the ETS).
  - Landowner perceptions of forestry and government (both central and local).
  - Availability of information, support, and leadership.
  - The absence of a co-management or co-governance model with Ngāti Porou.
- Reduced erosion and sediment yields through intervention (i.e. the treatment of eroding and erodible land) would appear to be consistent with the aspirations Ngāti Porou have expressed for the catchment. The exploration and adoption of approaches to treating

the erosion problem that, where appropriate, involve the use of natural reversion and indigenous species will be required. Approaches that provide employment for local people as well as opportunities for innovation, entrepreneurship, and regional economic development will also be needed to help address Ngāti Porou's aspirations around the restoration of economic independence.

Key conclusions

Geophysical & land use aspects

- Rates of natural erosion and sedimentation are high in the Waiapu catchment and deforestation during the late 19th and early 20th centuries has resulted in a significant and growing erosion problem. Larger rivers within the catchment are still aggrading and their channels are continuing to widen. Gully-derived sediment yields have increased between 1957 and 2008. Current annual sediment yields from the Waiapu River are very large in comparison to other rivers in New Zealand.
- Afforestation, reversion, and wide-spaced planted trees are all known to be effective in reducing erosion and about 54,000 ha of land in the Waiapu catchment has been afforested to date.
- It is estimated that the effective treatment of up to about 28,000 ha of grassland within the catchment is still required to attempt to address the erosion problem and move toward achieving some aspects of the desired state. There is an urgent need to effectively treat this 28,000 ha area, otherwise sediment yields will continue to increase, as unplanted gullies continue to grow in size.
- The majority of the highly erodible land under grassland within the Waiapu catchment is in private ownership (general and Māori title). Therefore, the uptake of treatment will be voluntary except in areas where it is required under the Gisborne Combined Regional Land and District Plan (i.e. Land Overlay 3A). Unless further regulation is introduced to require effective treatment of areas of eroding and erosion-prone land not currently covered by Land Overlay 3A, the rate of uptake of existing incentive schemes (e.g. the East Coast Forestry Project) will need to be increased.

Social, cultural, & economic aspects

- The catchment and the people who depend on its resources have been subjected to a series of environmental, social, and economic shocks for over a century. These shocks have had impacts on the wellbeing of Ngāti Porou in the catchment and appear to have played a contributory role in the current low socio-economic profile for the area and a degradation of cultural values of importance to Ngāti Porou.
- Interventions to date, based on this brief and provisional assessment, have not fully addressed or embraced the aspirations of Ngāti Porou as far as can be assessed or reflected in their holistic view of the interconnectedness of the wellbeing of the community and environment — that the health of the river and the people are one.
- Any attempt to develop and implement interventions to address the erosion problem in the Waiapu catchment without the direct and active participation of Ngāti Porou (as mana whenua) and local communities is unlikely to be successful.
- In defining future courses of action and interventions to reduce the erosion and its effects, it should be recognised that they may lead to undesirable as well as desirable socio-economic and cultural impacts. Future proposed catchment management policies or erosion control programmes will therefore require careful environmental and social impact assessment and be informed by the perspectives, values, and experiences of Ngāti Porou.

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1 General introduction

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On 22 December 2010, the Crown and Ngāti Porou signed a Deed of Settlement to address all Ngāti Porou's historical Treaty of Waitangi Claims. The Deed recognised the significance of the Waiapu River to Ngāti Porou and the impacts of erosion on the river catchment. Under the Deed, the Crown and Ngāti Porou have committed to develop an enhanced relationship through an accord to address contemporary issues within the Ngāti Porou rohe.

The Crown has established a Steering Committee to oversee (i) a stock-take and review of reports and information related to erosion in the Waiapu River catchment and (ii) an assessment of the size and scope of issues impacting on erosion in the catchment. The Steering Committee is comprised of representatives from Ngāti Porou, the Gisborne District Council (GDC), the Department of Conservation (DoC), the Ministry for the Environment (MfE), and the Ministry of Agriculture and Forestry (MAF).

MAF commissioned the Waiapu River Catchment Study, the purpose of which was to investigate the geophysical, social, cultural, and economic dimensions of the erosion problem in the Waiapu River catchment in order to inform future policy decisions with respect to the catchment in the context of the Deed of Settlement. This report presents the work undertaken on the Waiapu River Catchment Study. The report includes:

- An outline of existing knowledge related to the (i) geophysical and land use aspects and (ii) social, cultural, and economic aspects of erosion and land use change within the Waiapu River catchment and the wider East Coast region.
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- A description of a baseline from which future progress in the Waiapu catchment may be measured (benchmarking) for the (i) geophysical and land use aspects and (ii) social, cultural, and economic aspects of erosion against the values of Ngāti Porou for the catchment and well-being of the people.
- An outline of the project team's interpretation of a desired state for Ngāti Porou and consideration of possible options for addressing the erosion problem.
- Assessments of the scope (size and scale) of the erosion problem in the catchment and critical evaluations of the effectiveness of erosion mitigation measures for the (i) geophysical aspects and (ii) social, cultural, and economic aspects of erosion.

The report consists of eight sections. Following this general introduction, Chapter 2 presents a review of the relevant literature relating to the geophysical and land use aspects of the erosion problem in the catchment. Chapter 3 provides a review of the relevant literature relating to the impacts of land use change and erosion on Ngāti Porou in the catchment. A description of the baseline from which future progress in the Waiapu catchment may be measured (benchmarking), a scope assessment, and a critical evaluation of current efforts – East Coast Forestry Project (ECFP) & Land Overlay 3A (LO3A) in particular – to address the erosion problem is given in Chapter 4 in relation to the geophysical aspects and in Chapter 6 in relation to the social, cultural, and economic aspects. Chapter 5 describes a geospatial analysis of potential and present erosion severity in relation to land use class and land tenure, and includes an examination of the areas of land within the ECFP and LO3A target areas that are yet to be treated. In Chapter 7 we make comment on possible options to control erosion in order to move toward addressing aspects of a desired state for the catchment and comment on the land use change implications of and potential issues and opportunities around the various approaches to the revegetation of eroding and erosion-prone land is also made. The key conclusions of the study are given in Chapter 8. Ancillary information is provided in Appendices 1-11 and identified research gaps and recommendations for future work are provided as an Annex.

2 Literature review – a review of the geophysical & land use aspects of the erosion problem in the Waiapu catchment

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2.1 Introduction

GNS Science was subcontracted by Scion to prepare a review of existing information on the geophysical component of the erosion problem in the Waiapu catchment, identify any gaps, and make recommendations for addressing those gaps. The term geophysical, as used in the MAF RFP, includes all physical aspects of the catchment (i.e. geological, biological, and hydrological). This review has largely drawn on documents that have previously collated data and knowledge on, or relevant to, the Waiapu catchment (e.g. Harmsworth et al., 2002; Rosser et al., 2008; Basher et al., 2008), together with other relevant sources such as research from the neighbouring Waipaoa catchment (e.g. Eden and Trustrum (eds.), 1994; DeRose et al., 1998; Gomez, et al., 1999; Hicks et al., 2000; Marden et al., 2005).

The review undertaken by Harmsworth et al. (2002) was part of a joint project between Te Whare Wananga o Ngāti Porou and Landcare Research New Zealand Ltd (Manaaki Whenua). The project used both mainstream science and Māori knowledge to establish a knowledge base of environmental changes to the catchment through time, to determine factors affecting catchment and river health, to define Māori values and aspirations, and to build a model for community participation in research and sustainable land management planning. A series of GIS maps was produced to show the spatial distribution of environmental and cultural information for the catchment.

Rosser et al. (2008) collated, reviewed, and summarised all known relevant published and unpublished material, including contract reports, research papers, theses, maps, posters, and newspaper articles etc., pertaining to the physical resources of Waiapu catchment, East Coast. They produced a written review, along with an extensive annotated bibliography in Reference Manager. The 2008 review was prepared for Gisborne District Council (GDC), and was funded by an Envirolink Grant. The main findings were that deforestation initiated the erosion, the catchment response was rapid, and woody vegetation/afforestation[1] is the most effective method for controlling erosion at the catchment scale. The review included a DVD with the Reference Manager database and maps showing the spatial extent of biophysical aspects.

Basher et al. (2008) reviewed the literature on the prevention, treatment, and management of hill country erosion in New Zealand. An inventory and synthesis of existing knowledge and current work on erosion processes, mitigation options and social learning in the management of hill country erosion was compiled. This work was not specific to the Waiapu, but summarised the state of knowledge on the management of erosion in New Zealand hill country and included important information relevant to the current study.

To aid the reader, the main findings for each section are listed (as bullet points) at the end of the section.

2.2 Background

The Waiapu River is formed by the joining of the Mata and Tapuaeroa Rivers. Originating in the Raukumara Range, these rivers drain a catchment area of 1734 km^2 (Figure 2.1). The Waiapu River has one of the highest sediment yields in the world, with an average annual suspended sediment yield of ~35 Mt/yr, 2.5 times higher than that of the similarly sized and adjacent Waipaoa catchment (Hicks et al., 2000). This equates to a specific yield of 20,520 $t/km^2/yr$ (Hicks et al., 2000). The high sediment yield is attributed to a combination of unstable rock types (lithology), the occurrence of relatively high rainfalls, and wholesale deforestation for conversion to pasture in the historic period. Deforestation that began in the late 19th Century led to the destabilisation of hillslopes and the development of extensive gully erosion, earthflow and slump failures, and shallow landslides. Ongoing erosion together with the high incidence of significant storm events has resulted in the in-filling (aggradation) of river channels with a consequent increase in the incidence of flooding of low lying areas and potential threat to the township of

[1] Note that in this report, the term ‗afforestation' includes both commercial and protection forestry.

Ruatoria. Most sediment is generated from areas of pastoral land where point sources such as gullies, earthflows, and slumps have been in existence for several decades. In the absence of treatment, gullies have grown in size and the earthflows & slumps have increased in activity. In addition, many new features have been initiated, particularly gullies and shallow landslides, usually in response to heavy rainfall events. The term “shallow landslide” is used in the scientific literature in relation to the Waiapu catchment, and is synonymous with the term “soil slip” as used by GDC, and in the New Zealand Land Resource Inventory (NZLRI). For consistency, throughout the remainder of this review the term shallow landslide is used.

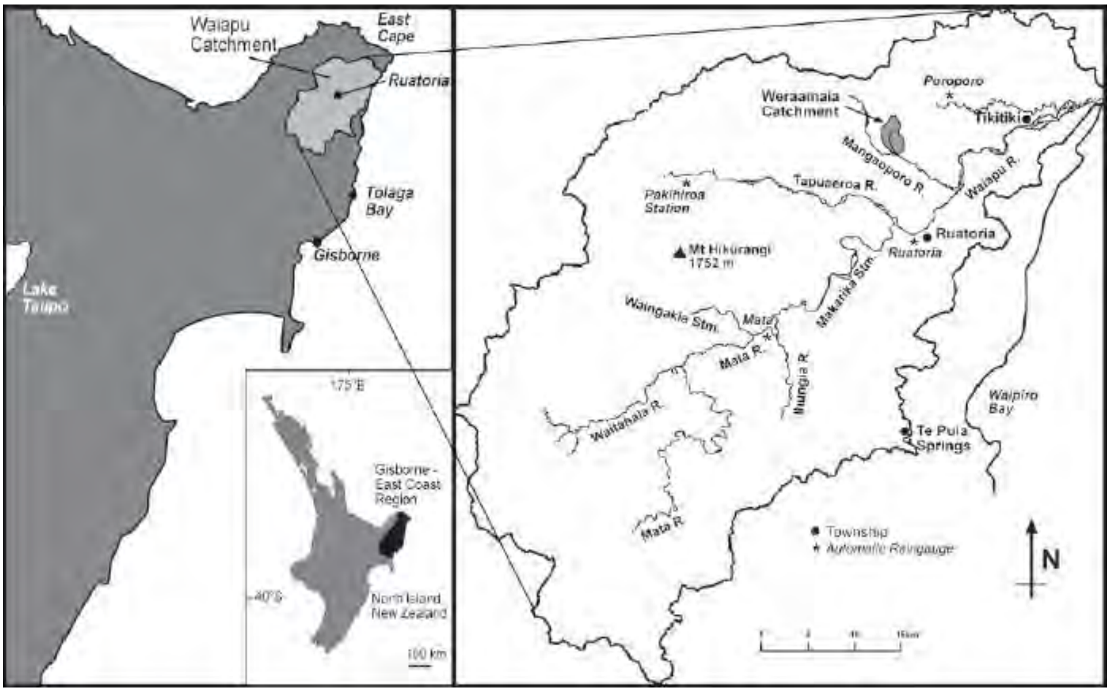


Figure 2.1. Location of the Waiapu catchment, East Coast. The major tributaries are shown on the right (reproduced from Parkner et al., 2007).

2.3 Tectonic setting

The landform pattern and associated widespread and severe erosion in the Waiapu catchment, though largely controlled by rock type, also reflects the tectonic history of the region. Subduction of the Pacific Plate beneath the Australian plate at a rate of 47 mm/yr (Wallace et al., 2009), has led to deformation and high uplift rates (1–4 mm/yr) of the Raukumara Peninsula (Mazengarb & Speden, 2000). Subduction occurs at the deep Hikurangi Trough (3500-4500 m b.s.l.) 70 km east of the coast, and the top of the Pacific Plate lies some 10 km below the Waiapu catchment. Uplift of the Raukumara Range (~500–1500 m a.s.l.) occurs mainly as a result of subduction of the anomalously thick, buoyant, Pacific Plate and overlying sediments (Reyners & Cowan, 1993; Litchfield et al., 2007). Uplift of the coast and submarine ridges offshore to the east occurs on faults and folds in the upper (Australian) plate. Earlier in the history of the subduction zone numerous faults and folds also deformed the eastern Raukumara Peninsula (Mazengarb & Speden, 2000), but few on-land faults are active today (Berryman et al., 2009).

Ongoing deformation is recorded by the relatively high levels of earthquake activity (GEONET website), with the majority of small to moderate earthquakes occurring along the top of the subducting plate (e.g. Reyners & Cowan, 1993). Larger earthquakes of note include the 1914 East Cape Earthquake (Mw 6.6), the 1966 (Mw 5.6) and 2007 (Mw 6.6) Gisborne Earthquakes and the 1993 Ormond Earthquake (Mw 6.2) (Downes, 1995; Read & Sritharan, 1993; Francois-Holden et al., 2008). All of these caused significant shaking recorded in some of the towns and the 1914 East Cape Earthquake is reported to have triggered some landslides (Downes, 1995; see also Litchfield et al., 2009).

As a consequence of the regional tectonics, large-scale folding, faulting and the presence of numerous crush zones have altered many of the underlying rock types in the catchment. A zone of extreme erosion extends northward from the headwaters of the adjacent Waipaoa River, along the Mata and Tapuaeroa catchments in the Waiapu basin, to Waikura, near East Cape, and Ruatoria (Mazengarb & Speden, 2000). The zone of extreme erosion corresponds to areas of strongly fractured and faulted rock which locally include smectitic claystones (Mazengarb & Speden, 2000). Most of the unstable rocks (mudstone, argillite, melange, smectitic claystone) belong to the East Coast Allochthon – an Allochthon is a body of rock that has been moved, often considerable distances, from its original site of deposition) – and large-scale crushing and shearing has made many of these susceptible to gully and deep-seated earthflow erosion (Page et al., 2008). Some parts of the Waiapu catchment, the Ihungia catchment for example, have been subjected to multiple phases of faulting, and thrusting, (Kenny, 1980) where the crushed and sheared nature of many of the rock types makes them prone to very high “natural” or “geologic erosion” rates whether under natural forest or pasture (Kenny, 1980).

2.4 Geology & landforms

A complex pattern and wide range of rock types are present in the Waiapu catchment, the major ones being Cretaceous argillite and greywacke, and Tertiary and Quaternary mudstone and sandstone (Mazengarb & Speden, 2000). Most rocks are sedimentary except for small areas of Late Cretaceous to Early Tertiary volcanics. The older Mesozoic rocks underlie the Raukumara Range in the headwaters of the catchment.

Major volcanic eruptions from Taupo and Rotorua volcanic centres during the last 100,000 years have deposited a number of airfall tephras over the catchment (Yoshikawa et al., 1988). However due to high erosion rates, tephra cover is now patchy, thin, or has been completely removed. The presence or absence of tephra has been used by researchers to indicate the level of landscape stability in the adjacent Waipaoa catchment (Marden et al., 2008).

O'Byrne (1967) recognised that there was a clear relationship between rock type and landform. He arranged rock types in the Gisborne-East Coast region into groups in order of increasing severity of erosion and described landforms, erosion types, and soils typically associated with each rock type grouping. Perhaps the most useful grouping of rock types within the Waiapu catchment was made by Harmsworth et al. (2002), who identified 31 principal Groups and Formations (Map 8 in Harmsworth et al., 2002) and related each Group to the forms and extent of erosion that typically occurs on them. Each Group and Formation can comprise up to 10 different rock types (e.g. sandstone, mudstone, and argillite).

There have been numerous geological-stratigraphic surveys in the area, including those by Kingma (1964, 1965), Moore et al. (1989), and more recently Mazengarb & Speden (2000). Three main structural features are recognised in the Waiapu catchment (see Figure 2.2) (Moore & Mazengarb, 1992; Mazengarb & Speden, 2000):

1. Motu Block, *in situ* Mesozoic (65 to 144+ million years) strata overlying Torlesse basement rock in the west;
2. East Coast Allochthon (ECA), which includes softer (often highly erodible) Cretaceous to Paleogene (23.8 to 144 million years) rocks in the east; and
3. Neogene (Miocene–Pliocene; 2.4 to 25 million years) ‗cover' rocks of the Tolaga Group which overlie thrust sheets of the East Coast Allochthon in the northeast and south.

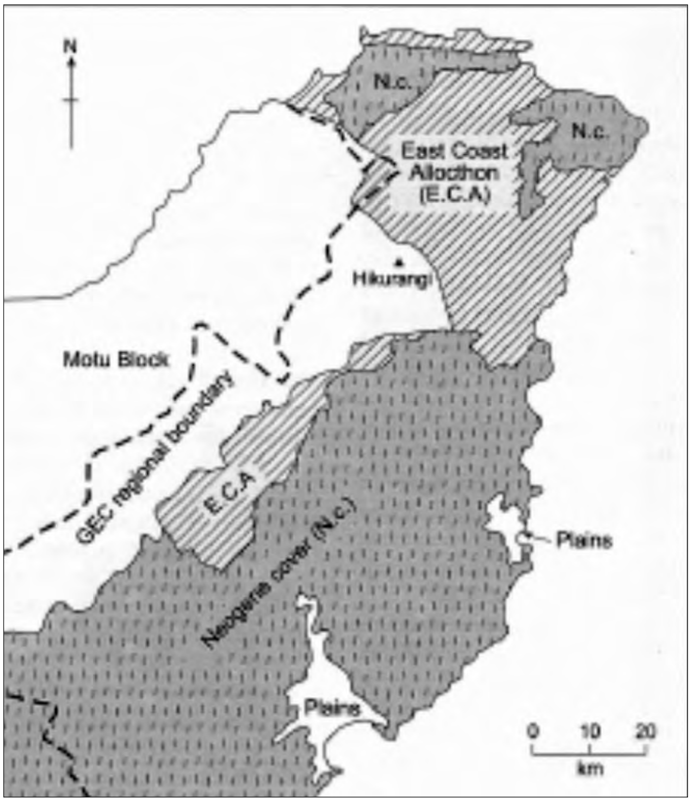


Figure 2.2. The distribution of the three main structural features of the Gisborne–East Coast Region (GEC) that are recognised in the Waiapu catchment (reproduced from Jessen et al., 1999).

2.4.1 Motu Block strata

The Early Cretaceous to Oligocene Motu Block strata includes greywacke and associated basement rocks. In the Raukumara area, Torlesse basement includes indurated, alternating, thinly bedded, fine-grained sandstone and mudstone, thick sandstone and massive mudstone, with some minor conglomerate and pebbly mudstone. The rock types are highly durable and form a rock mass which is typically highly fractured, brecciated, and folded. There are rare areas of melange, which includes blocks of chert, spilitic basalt, and limestone (Mazengarb & Speden, 2000).

2.4.2 The East Coast Allochthon (ECA)

Allochthonous rocks are those that have been moved from their original site of deposition. In the Gisborne–East Coast Region (GEC) the ECA consists of a series of moderately dipping thrust sheets, which displaced early Cretaceous to Oligocene age strata tens to hundreds of kilometres from their original sites of deposition. The displacement resulted from a phase of major thrust faulting, around the late Oligocene-early Miocene (Moore & Mazengarb, 1992). Over large areas in the Waiapu catchment the allochthonous rocks have been thrust over in-situ Cretaceous to early Miocene rocks as a result of the onset of the southwest to SSW directed subduction of the Pacific plate beneath the Australian Plate (Mazengarb & Speden, 2000). As a result of the large amount of displacement, the most erodible rocks in the catchment belong to the East Coast Allochthon.

The distinctive peaks of Mounts Whanokao, Hikurangi, Aorangi, Wharekia, and Taitai consist of erosion-resistant Cretaceous-aged Taitai and Mangaohewa sandstones surrounded by the more erodible and highly tectonised mudstones and sandstones of the Mokoiwi Formation (also Cretaceous in age).

2.4.3 Neogene (late Tertiary) cover strata (Nc)

In the northeast of the catchment, basement rocks (autochthonous) and rocks of the ECA are unconformably overlain by a sequence of early Miocene to Pliocene age sedimentary strata. These younger rocks are more stable than many of the older ‗unstable' allochthonous rocks, and support steeper slope angles (Winkler, 1994). Areas underlain by Pliocene-aged sandstone have distinctively steep landforms and remnants of plateaux.

For simplicity, the rock types described above are grouped into two major categories: Cretaceous and Tertiary rocks. Cretaceous rocks include those of the Motu Block strata, and the highly deformed East Coast Allochthon. Tertiary rocks consist of younger Neogene sedimentary rocks. The Cretaceous rocks generate the majority of the coarse gravel and boulders supplied to the river network. However, the high degree of deformation makes them susceptible to gully erosion, and sediment supplied to the rivers tends to break down rapidly (Page et al., 2008). Landslides typically occur on the Tertiary rocks, although gully erosion is also present. Cretaceous terrain underlies about 60% of the catchment (1158 km^2), while tertiary terrain occupies around 29% (504 km^2) of the catchment (Marden et al., 2008).

2.4.4 Main points

- The widespread and severe erosion in the Waiapu catchment is lithologically and structurally controlled, and also reflects the tectonic history of the region.
- Contributing factors are:
    - High uplift rates and deformation associated with the subduction of the Pacific plate beneath the catchment,
    - A high incidence of earthquakes,
    - The presence of highly faulted, fractured and folded rocks associated with the emplacement of the East Coast Allochthon.

- There are a wide range and complex pattern of rock types in the catchment, some of which are very susceptible to erosion.
- Most of the unstable rocks (mudstone, argillite, melange, and smectitic claystone) belong to the East Coast Allochthon.
- Cretaceous rocks underlie about 60% of the catchment; Tertiary rocks underlie about 29% of the catchment.
- Cretaceous rocks are particularly susceptible to gully erosion because of the high degree of deformation of the rocks.

2.5 Soils

The broad soil pattern in the Waiapu catchment is related to combinations of rock type, tephra cover (volcanic ash), topography, and rainfall. Information on soil patterns in the Waiapu catchment has been recorded in the New Zealand Land Resource Inventory (NZLRI) GIS database for the region, and mapped using landform-based polygons. All soils in the Gisborne–East Coast region were classified according to the New Zealand Soils Classification (NZSC) of Hewitt (1998). Soil maps for the Waiapu catchment have been generated using the previous regional NZLRI database (Maps 11&12 of Harmsworth et al., 2002).

Recent Soils make up 53.6% of the catchment area, Brown Soils 21.5%, Raw Soils 12.4%, Allophanic Soils 8.3%, and Podzols 3.4%. Minor areas of Gley Soils, Pallic Soils, and Pumice soils have also been found. More detailed information on the general physical, biological, and chemical properties of these soil Orders can be found in Hewitt (1998).

In the Waiapu catchment, most erosion occurs on steep slopes or on unstable rock types in mountainous and hilly terrain (Eyles, 1983, 1985; O'Byrne, 1967). The focus of this review is on the geophysical aspects of the erosion problem so we have concentrated on describing the soils of the hill country and steeplands. However, a brief outline of the soils of the river flats, terraces and sand dunes is given here and the reader is referred to the publications referenced below for more information on these soils.

2.5.1 Soils on the river flats, terraces, & sand dunes

Soils on the river flats and terraces in the Waiapu valley are formed from alluvium derived from the erosion of strongly indurated sedimentary rocks in the headwater catchments (Kingma, 1965). Rijkse (1980) mapped and described the physical and chemical properties of the soils on the river flats and terraces. The soils on the active floodplain are often flooded resulting in rapid accumulation of silt and sand derived mainly from eroded sediments from hill country and mountain lands, and near the coast, windblown sand. Due to the frequency of overbank flooding, Recent Soils on the floodplains exhibit young, weakly weathered A-C profiles, with locally buried topsoils. Further from the channel, soils have profiles that are more developed, due to the greater time periods between flooding and additions of new material. Intermediate and high terraces are mantled with cover beds consisting of airfall tephra (including, Waiohau Tephra, Mangaone Tephra, Rotoehu Tephra) and loess. Peat also occurs in small, isolated basins.

The Anaura soil series occurs on sand dunes near the Waiapu river mouth and is classified as Recent Soils derived from wind-blown dune sand. They exhibit dark topsoils about 7 cm thick with very friable structures overlying coarse sand with gravel (Rijkse, 1980).

2.5.2 Soils of the hill country & steeplands

Soils of the hill country and steepland areas have not been mapped in as much detail as those on the floodplains, and this reflects the poor state of knowledge of the properties and distribution of soils in the hill country areas of the Waiapu catchment (Rosser et al., 2008).

The intact (uneroded) soils of the hill country and steeplands in the Waiapu catchment generally have good drainage, are biologically active with good rooting medium, and P retention is moderate to high. The soils are formed from the underlying regolith (layer of weathered rock) which includes massive mudstone, argillite, basalt, and (where they still exist on the landscape) tephra from the Taupo Volcanic Zone to the west. The soils are classified as Brown Soils (Yellow-brown earths), and have distinct brown subsoils. However, on steep eroded slopes where the original forest soils have been removed by erosion, soils are generally skeletal and exhibit shallow, weakly developed topsoils with bedrock near the soil surface (Gibbs, 1959). These soils are classified as either Raw or Recent Soils in the NZSC (Hewitt, 1998).

In the Waiapu catchment, on areas of easier hill country, such as rolling land and terraces, ridge crests and more stable sites, Allophanic Soils (Yellow-brown loams) occur. Allophanic Soils tend to lose strength on disturbance. They have relatively stable topsoils, high water retention, active soil fauna, good rooting medium, and are generally well drained. Allophanic Soils often have limited fertility, and require additional phosphorus (phosphate retention is generally high or very high), potassium, and magnesium.

Pumice Soils are found on rolling and hilly lands where soil erosion has not removed the tephra cover. Soils are friable, sandy, or gravely and drain readily yet retain sufficient moisture for plant growth (Gibbs, 1959). These soils are physically excellent for pastoral land uses, but chemically many of the soils are poor and unbalanced, especially with regard to trace elements (P, N, S, Co, and in some areas Mo is too high) due to the composition of the underlying volcanic ash. In general, they are moderately fertile and capable of producing good pasture in areas that are not prone to erosion. When exposed or when the protective vegetation cover is removed, these soils are vulnerable to erosion by water and soil erosion on steep slopes is the main limitation to pastoral use. The dominant soil forming tephras in the Waiapu catchment are the Whakatane Tephra, Waimihia Tephra, Taupo Tephra, and the Kaharoa Tephra. The most widespread soil forming tephra is the Whakatane Tephra (5470-5600 cal. BP) (Gehrels et al., 2006) that occurs in the landscape as a fine-grained, sandy pumice deposit overlying sedimentary materials.

Podzols occur at higher altitudes within the Waiapu catchment, commonly >550 m a.s.l., typically where rainfall exceeds 1800–2000 mm year. They often form on substrates such as weathered greywacke, have low base saturation, low biological activity, limited rooting depth, and are of low natural fertility.

2.5.3 Main points

- Recent Soils occur on 53% of the catchment area and are related either to the frequent deposition of overbank sediment on the floodplains, or the removal of topsoils by landslide and gully erosion in the hill country and steeplands.
- Raw Soils occur on 10% of the catchment on eroded surfaces of gullies and landslides.
- The catchment was once covered in tephra deposits from the Taupo and Rotorua volcanic complexes. Pumice and Allophanic Soils are found on rolling and hilly lands where soil erosion has not removed the tephras. Soils are physically excellent for pastoral land uses, but chemically many of the soils are poor and unbalanced. These soils are also vulnerable to erosion by water and soil erosion on steep slopes is the main limitation to pastoral use.
- The dominant soil forming tephras in the Waiapu (where they remain) are the Whakatane, Waimihia, Taupo, and the Kaharoa. The most important soil forming tephra in the Waiapu catchment is the Whakatane Tephra that occurs as a fine-grained, sandy pumice deposit overlying sedimentary materials.

- Uneroded, intact soils in the hill country generally have properties that are favourable for plant growth. However, on slopes where the topsoils have been removed by erosion, topsoils are generally thin and weakly developed.
- Pasture production on eroded topsoils has been shown to be permanently reduced compared to uneroded topsoils, and only reaches 80% of uneroded production after 80 years.

2.6 Rainfall & rivers

2.6.1 Rainfall

The climate in the Waiapu catchment is warm temperate maritime, with warm moist summers and cool wet winters. Average annual rainfall in the Waiapu catchment is 2400 mm/yr, but varies from 1600 mm/yr at the coast to >4000 mm/yr in the headwaters (Hessell, 1980). The region's climate is strongly influenced by the El Nino/Southern Oscillation (ENSO), with an increase in major rainfall events during La Nina conditions, and severe and prolong droughts during El Nino (Marden et al., 2008).

The Waiapu catchment is subject to frequent intense rain storms. Erosion-generating storms have a recurrence interval of 2.6 years in the headwaters, and 3.6 years at the coast (Hicks, 1995). Extreme rainfall events typically occur during tropical cyclones that originate from the north during March-May (Page et al., 2000). Major storms (with rainfalls of >200 mm/day) and floods in the Waiapu catchment occurred in 1876, 1893–94, 1916, 1918, 1920, 1921, 1938, 1950, 1980, 1988, 1992, 1993, 2005 (July and October), 2009, 2010, and 2011. Information on storms, rainfall, flooding, and erosion was summarised by Harmsworth et al. (2002) and Rosser et al. (2008) from a range of sources including; Hill (1895), Cowie (1957), Tomlinson (1980), Rijkse (1980), Rau (1993), and Jessen et al. (1999), and data from 1988 to 2011 was downloaded from CliFlo (http://cliflo.niwa.co.nz/). From the late 1800s to 2011 there were over 57 extreme rainfall events that caused widespread damage. Daily rainfall from 1988 to 2011 is shown in Figure 2.3. The high frequency of storm events in the Waiapu catchment contributes to the high erosion rates (Page et al., 2001a).

Cyclone Bola in 1988 was the largest rainfall event on record, with 600 mm recorded in 4 days near the coast, and 900 mm in the headwaters. The Cyclone "Bola" flood in the Waipaoa River has been estimated as a 1 in 70 year return period event, (Peacock, 2007) based on the annual flood series developed by Reid (1999), and more recently as a 1 in 100 year (+/- 20%) event (NIWA, 2011). There are no estimates of storm return period for

Cyclone Bola sized events in the Waiapu catchment (D.H. Peacock, pers. comm.). Severe hillslope erosion, bed aggradation, and floodplain deposition resulted in an estimated $NZ10 million worth of damage in the Waiapu catchment (Glade, 1998). The Waiapu floodplain is unprotected by stopbanks and is frequently inundated during flood events. In addition, the river channel continues to aggrade and widen by bank erosion (Rosser et al., 2008).

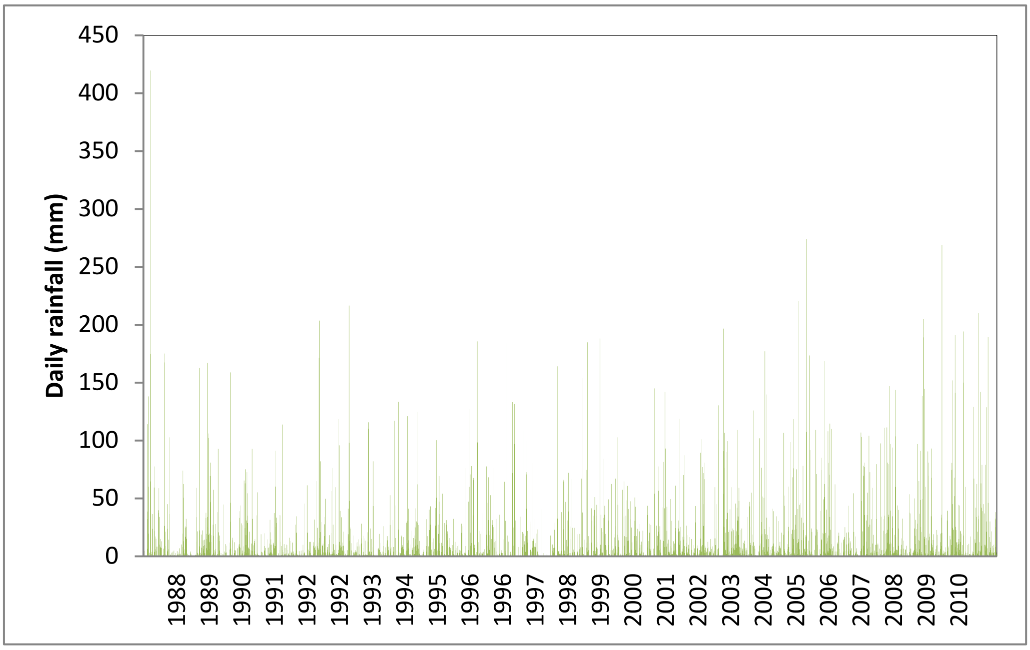


Figure 2.3. Daily rainfall totals for the Waiapu catchment, at the Te Puia rain gauge operated by NIWA (Data downloaded from http://cliflo.niwa.co.nz/).

2.6.1.1 Main points

- The catchment is subjected to frequent intense rainstorms.
- The recurrence interval for erosion generating storms is 2.6 years in the headwaters, and 3.6 years at the coast.
- The high annual rainfall and the high frequency of storm events contribute to the erosion problem in the Waiapu catchment.

2.6.2 Rivers

The Waiapu River (proper) is formed by the joining of the Mata and Tapuaeroa Rivers, approximately 26 km upriver from the mouth. Originating in the Raukumara Range, the Waiapu River drains a catchment area of 1734 km^2 (Figure 2.4). The Waiapu River is approximately 130 km in length from the headwaters of the larger Mata River, to the sea. Discharge is measured by GDC at Rotokautuku, near the State Highway 35 (SH35) Bridge. Mean annual flow in the Waiapu River is 86 m^3/s and the mean annual flood is

1750 m^3/s (D.M. Hicks, pers. comm.). The variation in flow throughout the year is strongly seasonal with the highest flow in the winter. Average summer flow is 37 m^3/s, and average winter flow is 133 m^3/s. The highest flow on record is 4624 m^3/s, recorded during Cyclone Bola in 1988 (D.M. Hicks, pers. comm.). Characteristics of the Waiapu catchment flows, suspended sediment gaugings, and suspended sediment loads are presented in Table 2.1. River discharge and flow gauging data is available from GDC, but no significant analyses of the data have been completed (G. Hall, pers. comm.).

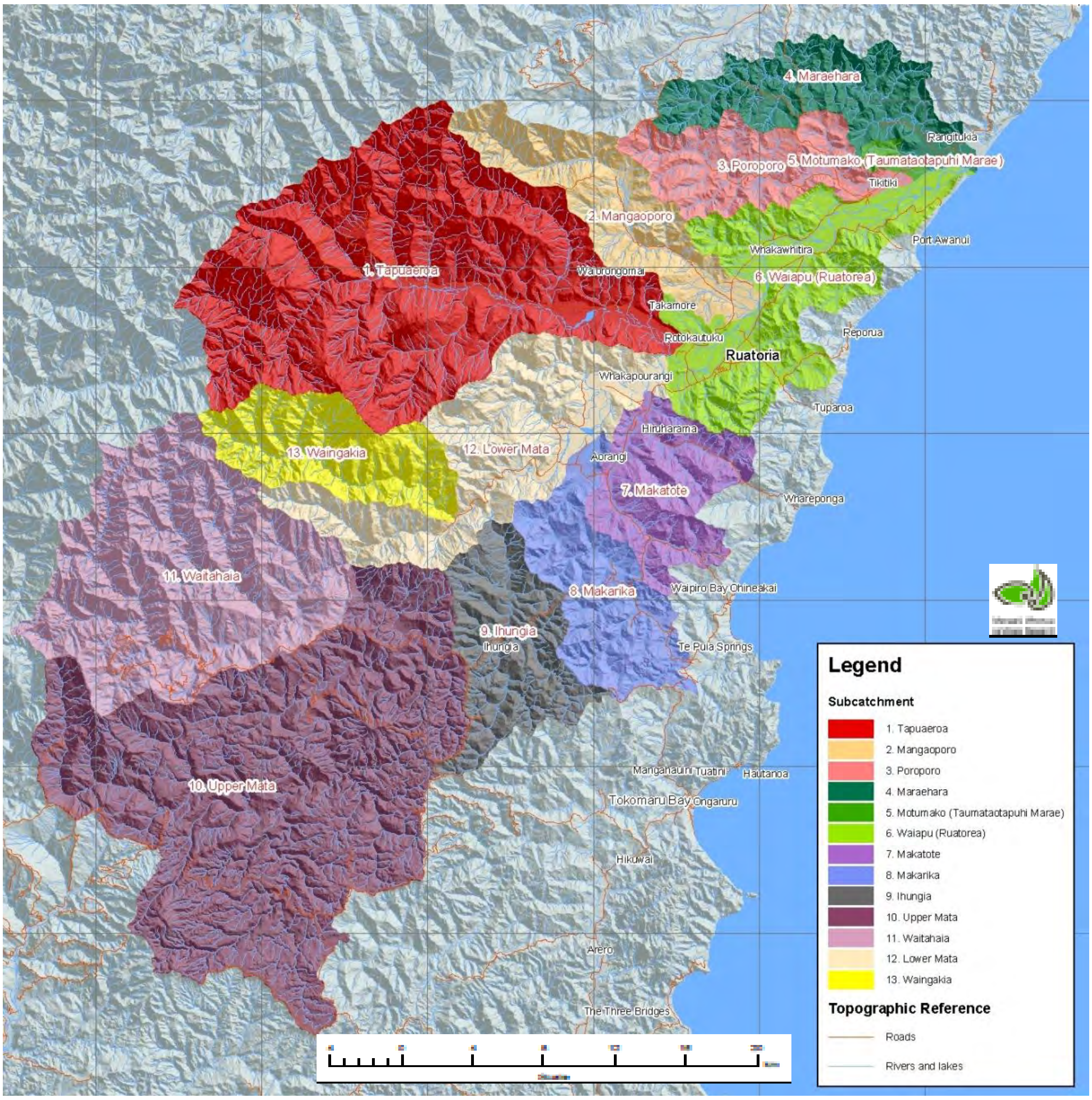


Figure 2.4. Map of Waiapu River drainage basin and sub-catchments (reproduced from Harmsworth et al., 2002).

Table 2.1. Characteristics of basin, flows, suspended sediment gaugings, and suspended sediment loads in the Waiapu catchment (D.M. Hicks, pers. comm.; reproduced from Rosser et al., 2008).

Characteristics	Waiapu River
Total catchment area, km^2	1,734
Gauging station	Rotokautuku (site 18309)
Drainage area, km^2	1378
Annual rainfall, mm (1961–1990)	1845
Period of flow record	1/1/1975 to 13/10/1997
Period of suspended sediment gauging	6/2/1973 to 16/10/1996
Number of sediment measurements	79
Mean flow (Q mean), m^3/s	86
Mean annual flood (QMAF) m^3/s	1750
Highest flow on record, m^3/s	4624
Maximum measured sediment concentration, mg/L	49 291
Minimum measured concentration, mg/L	~1
Maximum flow with sediment measurement, m^3/s	1353
Minimum flow with sediment measurement, m^3/s	4.51
Specific suspended sediment yield, $t/km^2/yr$	20 520
Suspended sediment yield, t/yr	28 276 560
95% CI factorial error	1.42
Load at Q < Q mean (mean flow), %[1]	1
Load at Q < Q MAF, %[2]	76
Suspended sediment yield for total catchment area, tonnes/yr	**35 581 680**

[1] 1% of the sediment load is carried by flows < mean flow

[2] 76% of the sediment load is carried by flows < MAF

2.6.3 Channel & bed material characteristics

Page et al. (2001a) subdivided the Waiapu River into four characteristic reaches, based on its channel morphology (Table 2.2). In the uppermost mountainous reaches where rivers drain indurated Cretaceous-aged lithologies (predominantly sandstones) the channel is typically narrow, single-thread, and steep. Further downstream (113 km from the river mouth) where the drainage network traverses less indurated Tertiary-aged mudstone and sandstone, the channel changes to a meandering, single-thread pattern incised within steep-sided gorges. From 50-26 km, the Waiapu River has a meandering channel bordered by intermediate and high terraces. In the reach nearest the coast the channel is a wide, shallow, braided, gravel bed between low terraces. The change in channel morphology from meandering to braided is coincident with the position of a crush zone in the underlying rocks of the lower catchment (Page et al., 2001a), and the confluence with the aggraded Tapuaeroa River. The characteristic channel morphologies are listed in Table 2.2. The average channel slope for the 26-0 km reach, is steeper than the lower reaches of many rivers, and is about ten times that of the Waipaoa River (D.H.

Peacock, pers. comm.). This may reflect both the uplift rate and the aggradation of the river bed.

The ratio of bedload to suspended sediment load in rivers that carry a very high suspended sediment load, such as the Waiapu, is typically low. The bedload component of the total sediment load in the Waiapu River is estimated to be about 3% of the sediment load (Gomez et al., 1999). This ratio is similar to the adjacent Waipaoa catchment, where bedload is less than 1% of the sediment load. Nevertheless, the bedload is still an important component of the sediment load in the Waiapu and is equivalent to approximately 1,050,000 t/yr. A result of the sediment load being largely composed of fine sediment is that three-quarters (76%) of the sediment load is carried by flows less than the mean annual flood (Table 2.1). The bedload or coarse fraction is particularly important in a river system as it is the sediment size fraction that conditions channel morphology and contributes to aggradation of the river bed (Martin & Church, 1995). A component of fine material will be stored within the coarse fraction as interstitial fines and thus also contributes to bed aggradation.

Table 2.2. Reach characteristics of the Waiapu River (reproduced from Page et al., 2001a). The distances represent kilometres upstream from the river mouth.

Reach	Channel morphology	Av. channel slope (m/m)	Av. channel width (m)
130-113 km	Narrow single-thread channel between steep mountain slopes	0.0482	33
113-50 km	Meandering, incised, single-thread channel through steep hills	0.0047	95
50-26 km	Meandering channel bordered by terraces	0.0036	212
26-0 km	Braided, gravel bed channel between low terraces	0.0021	598

Headwater sub-catchments such as the Waitahaia, Waingakia, and parts of the upper Mata (see Figure 2.4) have relatively high bedload yields, with large numbers of boulders and cobbles from areas of greywacke, consolidated and indurated sandstone and mudstone rock, but it is unlikely that this material will move far downstream without exceptionally high energy floods. Most streams and rivers in the highly eroded sub-catchments exhibit a large proportion of intermediate to fine particles, which, through exposure and flooding, contribute to the very high suspended sediment yields recorded in the catchment (Rosser et al., 2008).

A field investigation (Rosser, 2001) was undertaken to characterise surface and subsurface sediments for a number of tributaries of the Waiapu River where the underlying rock type could be characterised as being predominantly uniform for much of the channel length upstream of the sampling location. Particle size characteristics are presented in Tables 2.3 and 2.4. Samples were generally very poorly sorted with a high proportion of sand (>25%), reflecting the nature and proximity of the sediment supply (from erosion sources), and the inability of the stream to transport the material. Hayward (2001) sampled bed material in the Tapuaeroa and found that for both surface and subsurface samples, the particle size distributions were very similar; surface D_{50} was 25 mm, and subsurface D_{50} was 26 mm and that particle size distributions were either fine with a high silt/clay content (D_{50} ~0.18mm), or coarse with a high gravel content (D_{50} ~50mm).

Table 2.3. Subsurface sediment characteristics of channel deposits sampled from tributaries draining different rock types. D_x represents the particle diameter (D in mm) at which x% of the sample is finer.

Tributary	D50	D90	%sand
Unnamed Mangaoporo	138.3	421.1	8
Upper Mata	121.9	874.1	14
Waitahaia	112.6	232.4	3
Raparapaririki	58.3	481.1	4
Kopuaroa	34.9	102.6	1
Mangaoporo	30.5	154.2	5.5
Mangaraukokore	22.8	124.1	8.5
Mangawhairiki	22.6	107.7	21
Ihungia	21.2	60.8	16
Wereaamaia	20.8	205.2	16
Unnamed 1	19.7	208.1	21
Unnamed 2	16.9	124.2	3
Wairoa	10.9	48.5	21.5
Makomete	10.3	42.3	27
Mangakinonui	7.6	33.9	12
Whakoau	7.5	64.0	29
Mata	6.9	39.4	39
Mangaiwi	5.7	29.7	18

Table 2.4. Surface particle size for selected sites.

Tributary	D_{50}	D_{90}	% sand
Wairoa	4.6	26.4	26
Mata	7.2	29.3	41
Raparapariki	33.9	100.1	12
Ihungia	23.6	57.6	15
Mangakinonui	9.9	33.5	14
Mangaraukokore	21.9	67.4	18
Mangawhairiki	19.8	94.7	13
Mangaoporo	14.3	64.0	27
Unnamed (Mangaoporo)	9.7	45.3	30
Mangaiwi	11.7	23.7	19
Wereaamaia	46.5	128.0	0

Most of the rivers of the Gisborne District are aggrading, and accumulated gravel allows for sustainable shingle extraction (GDC, 2006). Gisborne District Council manages gravel extraction from the Region‘s rivers. GDC, road contractors, and forestry companies hold shingle extraction consents. The majority of extracted material is used in road construction and maintenance. Shingle quality varies with geology throughout the region — hard basement rocks such as greywacke, volcanic basalt and hard argillite provide good quality shingle, while mudstones and siltstones, such as in the Waiapu, provide poorer quality material that weathers rapidly to fine particles of silt and clay. Gravel extraction up to 30 m^3/yr from the beds of rivers and streams is a permitted activity in the Gisborne District. Above this, resource consent is required (GDC, 2003). In 2005 and 2006, 71,894 m^3, and 61,787 m^3, respectively, of bed material was extracted from the Waiapu River (GDC, 2006).

2.6.4 Water quality

GDC monitors water quality in the Waiapu, Mata, and Ihungia River catchments. Results of the river water quality monitoring for the above rivers show all have unacceptably high levels of suspended solids, but the pH, biological oxygen demand (BOD), dissolved oxygen, and ammonia levels are all considered good (GDC, 2006).

2.6.5 Suspended sediment yield

The suspended sediment yield of the Waiapu River is 20,520 t/km^2/yr, which is equivalent to an annual sediment load of 35 million tons of sediment being delivered to the ocean every year (Hicks et al., 2000; Kniskern et al., 2006a,b). The annual suspended sediment yield of the Waiapu River accounts for 16.7% of the total NZ yield to the coast from only 0.65% the NZ land area (Hicks et al., 2011). This represents ~0.2% of the total global input of sediment to the oceans (Syvitski & Milliman 2006).

In theory, changes in hill slope sediment generation should be reflected in changes in suspended sediment yields, which in turn can be an indicator of stream health. Gauging of suspended sediment concentration has been carried out by Gisborne District Council at the SH35 bridge near Ruatoria, and at a site on the Mata River. However, analysis of results shows a poor correlation between suspended sediment concentration and water discharge (D.H. Peacock, pers. comm.). This is because the river stage for the same discharge could be either rising or falling, or the antecedent rainfall could have fallen on different parts of the catchment — for example, one part of the catchment could be stable under natural forest, whereas another part is dominated by active gullies. Similarly, large variations in annual suspended sediment yields have been identified in the Waipaoa catchment. For these reasons no trends in suspended sediment yield were observable, and it is unlikely to be a useful future indicator.

2.6.6 Main points

- The Waiapu River has the highest suspended sediment yield of any river in New Zealand. The suspended sediment yield of the Waiapu River is 20,520 $t/km^2/yr$, which is equivalent to an annual sediment load of 35,000,000 t/yr.
- Mean annual flow is 86 m^3/s, and the mean annual flood is 1,750 m^3/s.
- There have been over 57 major flood events since the late 1800s. The highest flow on record was 4,624 m^3/s, recorded during Cyclone Bola in March 1988.
- The ratio of bedload to suspended sediment is very low (about 3%), but it is the bedload that conditions channel morphology and bed aggradation.
- Bed material is typically very poorly sorted, with a high proportion of sand.
- As a result of the sediment load being largely composed of fine sediment, three-quarters (76%) of the sediment load is carried by flows less than the mean annual flood.
- There is a poor correlation between suspended sediment concentration and water discharge and large variations in annual suspended sediment yields have been identified in the Waipaoa catchment. A lack of observable trends in suspended sediment yields means that this parameter is unlikely to be a useful future indicator.

2.7 Vegetation & land use

2.7.1 Historical vegetation cover

An 1840 vegetation map was compiled by Harmsworth et al. (2002) using existing vegetation and historical information, GIS classification and inference, district planning records, local Māori knowledge, and historic photographs. This map (Figure 2.5) shows that about 80–90% of the catchment was in native forest at 1840. The catchment probably remained in this condition until about 1890. The area between the Waiapu River and the coast had been partially cleared and burnt by 1840, and was in scrubby coastal vegetation, manuka, and bracken. The area west of the river to the Raukumara Range was largely in natural forest, except in small clearings near the river. Harmsworth et al. (2002) defined historical vegetation classes, and calculated their areas (Table 2.5). Descriptions for each of the historic vegetation types are given in Appendix 1. This provides an environmental baseline for the catchment, showing how it looked in 1840 before large-scale deforestation.

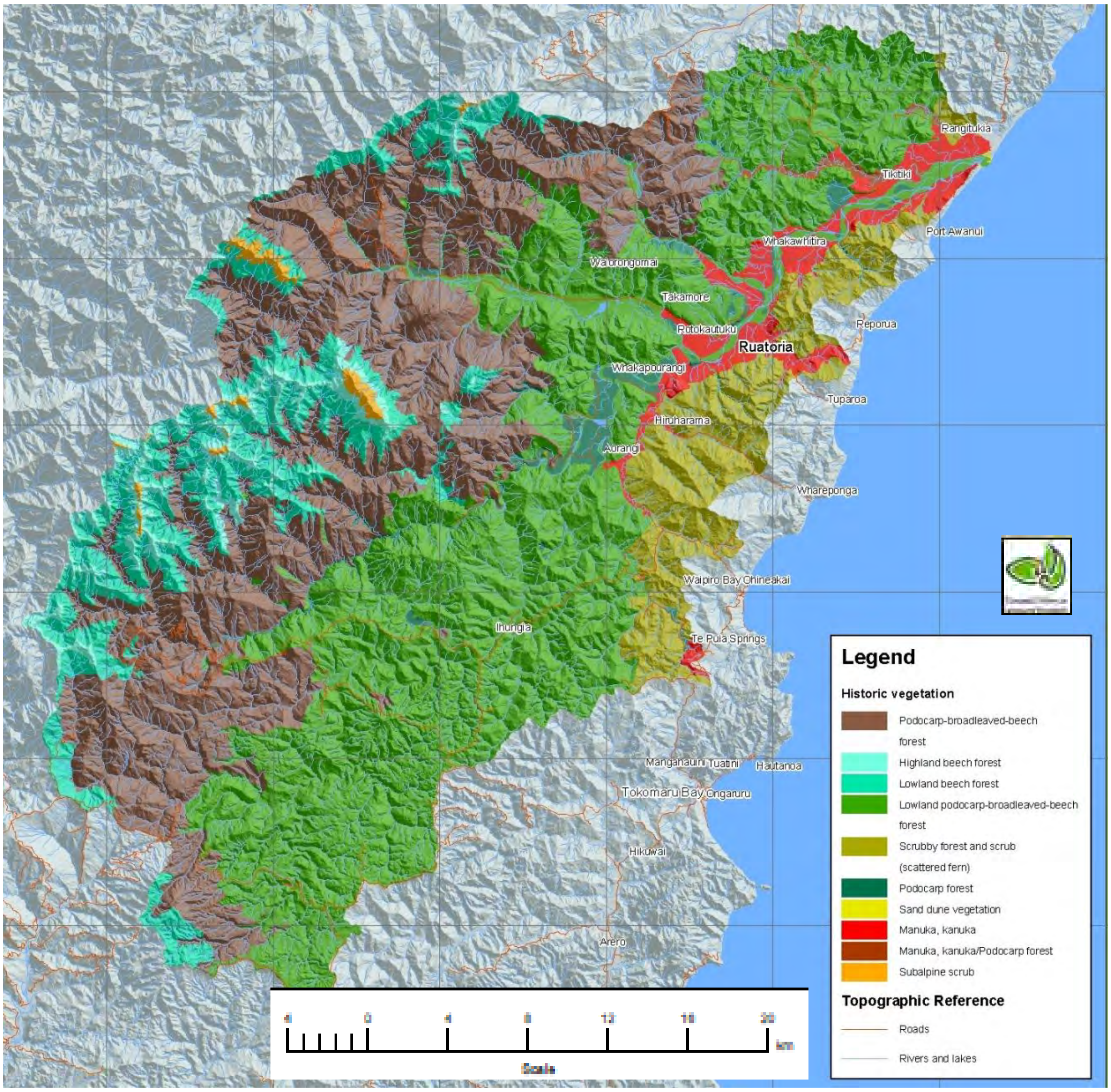


Figure 2.5. Vegetation cover map of the Waiapu catchment in 1840 (reproduced from Harmsworth et al., 2002).

Approximately 42% of the catchment area was under lowland podocarp-broadleaved forest with a further 33% under Podocarp-broadleaved-beech forest (Table 2.5).

Table 2.5. Vegetation cover of the Waiapu catchment in 1840 (from Harmsworth et al., 2002).

Vegetation cover - 1840	Area of total catchment (ha)	Area (% of Waiapu catchment)
Podocarp forest	3464.8	2
Lowland podocarp-broadleaved forest	71 905.4	41.5
Podocarp-broadleaved-beech forest	56 547.9	32.6
Lowland beech forest	16 166.2	9.3
Highland beech forest	4236.1	2.4
Scrubby forest and scrub with scattered fern	13 438.9	7.7
Manuka, kanuka/Podocarp forest	533.6	0.3
Manuka, kanuka	6084.9	3.5
Subalpine scrub	1013	0.6
Sand dune vegetation	21.1	0.01
Total	**173 411.9**	**100.00**

2.7.2 Present vegetative cover

The current (as at 2008) status of the vegetation cover within Waiapu catchment (Figure 2.6) is based on the Ministry for the Environment LUCAS 2008 land use mapping (http://www.mfe.govt.nz/issues/climate/lucas/data/index.html).

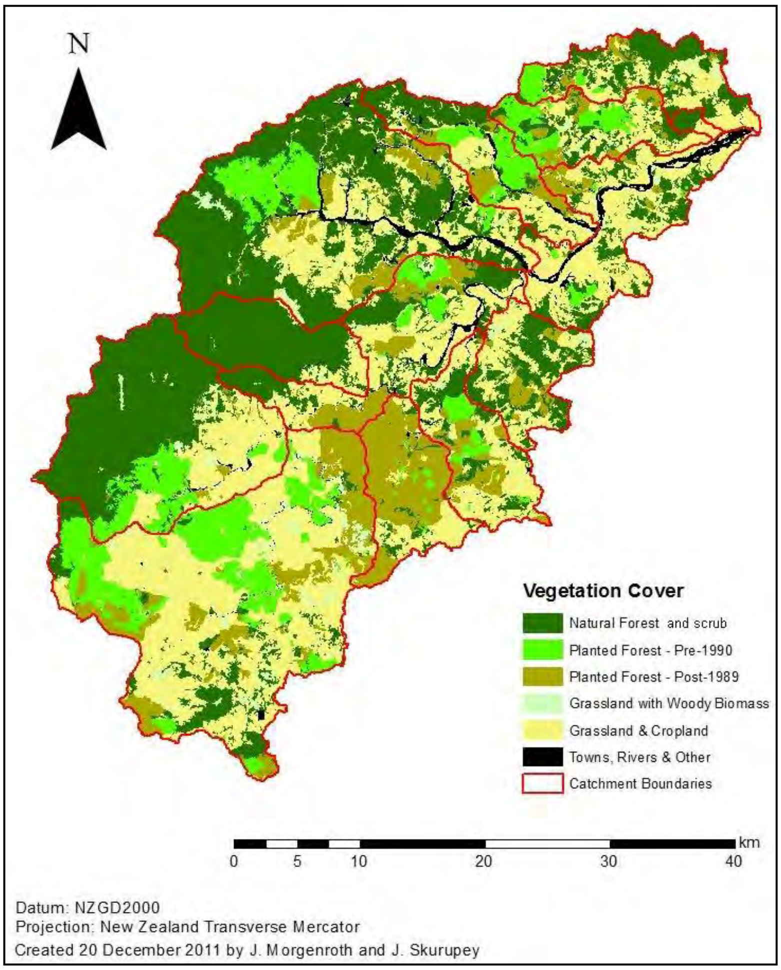


Figure 2.6. Present vegetation cover as at 2008 (Data from MFE LUCAS 2008 mapping http://www.mfe.govt.nz/issues/climate/lucas/data/index.html).

The current vegetation map shows that the dominant land uses/vegetation in the Waiapu are natural forest and scrub (60,104 ha, 34.6%), exotic forest (pine) (43,783 ha, 25.2%), and grassland (60,622 ha, 34.9%). Comparison of the 1840 vegetation map to the present day vegetation shows that the area of natural forest has decreased by 61%, and the area of pasture has increased by 34.9%, and pine plantations have increased by 25.2%. Scrub area is also thought to have increased by about 9%. Land areas associated with the current land uses within the catchment, and the proportions of the catchment these represent, are given in Table 2.6.

Table 2.6. Present vegetation (as at 2008) of the Waiapu catchment (data from MFE LUCAS 2008 land use mapping: http://www.mfe.govt.nz/issues/climate/lucas/data/index.html).

Vegetation type	Area (ha)	% of Waiapu catchment
Natural forest and scrub	60104	34.6
Planted forest –pre-1990	20448	11.8
Planted forest –post-1989	23285	13.4
Grassland with woody biomass	5486	3.1
Grassland	60622	34.9
Cropland	369	0.2
Towns, rivers, and other	3500	2.0
Total	**173814**	**100.0**

2.7.3 Ecological conservation areas

2.7.3.1 Department of Conservation estate (DOC)

Existing Protected Natural Areas (PNAs) comprise approximately 8,400 ha (~5% of the Waipu catchment) (Leathwick et al., 1995). They are concentrated mostly in the west, and are strongly biased towards high-altitude sites. Protected areas at lower altitudes contain either small fragments of primary forest or more extensive areas of advanced secondary vegetation on reverted farmland. About 2,500 ha of Māori land has been obtained as reserve under long-term lease (Shaw, 1989). It spans a range of rolling to steep coastal hills with mixed broadleaf forest and regenerating shrubland and grass.

About 26% of the catchment is presently covered by natural forest comprising the Pukeamaru and Waiapu Ecological Districts (Reigner et al., 1988; Shaw, 1989), mainly located in the critical headwaters of the catchment. The Waiapu Ecological District comprises predominantly coastal lowland and hills below 600 m a.s.l. (Shaw, 1989) where there are only very limited remnants of natural vegetation. The Pukeamaru Ecological District covers 98,000 ha at the northern end of East Cape. A large proportion of the land in the Pukeamaru Ecological District is Māori land, with some small pockets of freehold and Crown land. The area includes areas of coastal and lowland natural forest, scrub, wetlands, and sand dune country.

2.7.3.2 Nga Whenua Rahui

Nga Whenua Rahui was established in 1991 to protect, by providing incentives for voluntary conservation, those natural ecosystems on Māori land that represent a full range of natural diversity present in the landscape. It is presently administered by DOC. Landowners sign a 25-year covenant with DOC, who pays for costs such as fencing. The Nga Whenua Rahui kawenata agreement is sensitive to Māori values in terms of spirituality and tikanga. About five natural forest land blocks are protected under Nga Whenua Rahui in the Waiapu catchment.

There are currently approximately 3,100 ha of land (~2% of Waiapu catchment) protected by Nga Whenua Rahui. The areas protected range in size from 12 ha to 2,600 ha, the largest of which is located in the Wairongomai catchment. Other significant areas of Nga Whenua Rahui are located in the Tahora (Tapere Trust, 650 ha) and Maungahauini (266 ha) areas. With landowner and whanau support, many existing areas of natural forest on private land could be protected under Nga Whenua Rahui, and protection under Nga Whenua Rahui should be promoted in the catchment (Rosser et al., 2008).

2.7.4 Main points

- In 1840 80-90% of the catchment was under natural forest.
- In 1840 there were small areas of cleared land along the river and near the coast that Ngāti Porou used for food production.
- The current vegetation (as at 2008) map shows that the dominant vegetation in the Waiapu catchment is natural forest (25.7%), exotic forest (pine) (22.4%), and scrub (12.5%).
- About 26% of the catchment is presently covered by natural forest comprising the Pukeamaru and Waiapu Ecological Districts. Included in this figure are 8,400 ha of Protected Natural Areas (PNAs), and approximately 3,100 ha of land protected by Nga Whenua Rahui.

2.8 History of settlement & land use

Māori (Ngāti Porou) settlement was widespread in the Waiapu valley since about the fourteenth century (Murton, 1968), and there was a large Māori population in the area up until the 1880s. Prior to 1840 there were approximately 3,000 inhabitants at Whakawhitira Pa, in the lower reaches of the Waiapu catchment (Harmsworth et al., 2002). The local Māori caused minor modifications to the forest cover by accidental burning, or by clearing land for gardens. However, as discussed in Section 7.1, ~80-90% of the catchment was in natural forest at 1840 (Harmsworth et al., 2002). There were some small clearings in an area east of the Waiapu River where scrub and coastal forest had recolonised following partial clearance and burning and there were extensive areas around the river that had been cultivated by Ngāti Porou for food production.

European settlers arrived in the late 1800‘s, and began clearing the land for pastoral farming. The main period of clear-felling and burning started in about 1890 and had concluded by 1920 (Harmsworth et al., 2002). The clearing of land for pastoral farming was encouraged by Governments of the time by providing incentives such as fertilizer subsidies, tax breaks for development of land, discounted loans, and a guaranteed minimum livestock price for farmers (Rhodes, 2001). A livestock incentive scheme also provided payments for increasing stock numbers, which inadvertently encouraged farmers to run more stock than the land could support, and in the late 1970‘s, a Land Development Encouragement Loan was introduced to increase production (Rhodes, 2001). A priority of the scheme was to clear unimproved or reverted hill-country (MAF, 1981). Much of the land cleared was steep marginal hill country. This was occurring at the same time as protection forests were being established under the East Coast Project to mitigate the effects of erosion.

Table 2.7 compares the area of present (as at 2002) vegetation types to the environmental baseline for the catchment in 1840, illustrating the drastic decline in natural forest accompanied by an increase in pasture and exotic forest.

Table 2.7. Comparison of areas of vegetation types in 1840 and 2002. For the 1840 vegetation types, all types of natural forest were grouped together (Reproduced from Harmsworth et al., 2002).

Vegetation type	1840 Vegetation		2002 Vegetation		% change
	Area (ha)	% of Waiapu catchment	Area (ha)	% of Waiapu catchment	1840-2002
Pasture	0	0	59917	34.6	**+34.6**
Natural Forest	165759	96	44540	25.7	**-69.9**
Exotic forest (Pine)	0	0	38769	22.4	**+22.4**
Scrub	6619	4	21749	12.5	+8.7
Cropland	?	?	362	0.2	0.2
Exotic forest (other)	0	0	277	0.2	0.2
Alpine Grass-/Herbfield/Tussock	1013	1	232	0.1	-0.5
Shelterbelts/Deciduous hardwoods	0	0	206	0.1	0.1
Built-up Area	0	0	38	0	0.0
Coastal Sand and Gravel	21	0	8	0	0.0
Vineyard	0	0	3	0	0.0
Water/River	?	?	5576	3.2	?
Other	0	0	1713	1.0	1.0
Sum	**173412**		**173408**	**100**	

2.8.1 Main points

- Māori (Ngāti Porou) settlement has been widespread in the Waiapu valley since about the fourteenth century.
- European settlers arrived in the late 1800's, and began clearing the land for pastoral farming.
- The main period of clear-felling and burning started in 1890 and had concluded by 1920.
- The clearing of land for pastoral farming was encouraged by Governments of the time by providing incentives.
- Since European settlement and deforestation, the area of natural forest has decreased by 70%, the area of pasture has increased by 34.6%, and pine plantations have increased by 23%. Scrub area is also thought to have increased by about 9%.

2.9 History of erosion response & land use impacts

A consequence of the change in land use from predominantly natural forest to pastoral farming has been a dramatic increase in erosion and sediment transfer. In some hill country areas the increase has been by at least an order of magnitude, indicating that land use-driven changes in vegetation override other controls on erosion in the Waiapu catchment (Page et al., 2008). As early as 1900, even before the clear-felling of natural forests had concluded, the effects of deforestation on the landscape were evident in the East Coast region (WSD, 1987). There were many landslides occurring on the newly deforested slopes, along with the activation and re-activation of numerous earthflows and gullies. River channel aggradation in response to the increased sediment supply was noted in the adjacent Waipaoa River as early as 1910, and river bed level rises of 10 to 30 m were recorded in the region by the 1930‘s (Allsop, 1973).

2.9.1 Hillslope response

2.9.1.1 Severity & extent of erosion

Erosion is strongly influenced by rock type, vegetative cover, and land use (O‘Byrne, 1967; Jessen et al., 1999). In the Waiapu catchment, most erosion occurs on steep slopes or on unstable rock types in mountainous and hilly terrain, often during high intensity and/or long duration rainfalls (i.e. storms) (O‘Byrne, 1967, Eyles, 1983, 1985). The main types of erosion in the Waiapu catchment are gully, earthflow and landslide erosion. These, along with other minor types of erosion in the catchment are defined in Appendix 2. Much of the eroded material is deposited in the channel network where it remains in storage until transferred further downstream during subsequent high intensity rainstorms.

Harmsworth et al. (2002) classified land in the Waiapu catchment according to erosion type and severity ranking from the NZLRI, and calculated the land area occupied by each land grouping for the Waiapu catchment and for each sub-catchment (Appendix 7.5 of Harmsworth et al., 2002) in a GIS. The resultant maps produced for the Waiapu catchment show that landforms with gully erosion occupy 22% of the catchment; landforms with landslide (including slump and debris avalanche) and surficial erosion (e.g. sheet, scree, and wind) occupy 48.3%; areas with dominant depositional surfaces occupy 2.8%; land with streambank and riparian slip erosion occupy 5.1%; and land with earthflow erosion occupy 13.9%. These maps are a useful tool to assist in identifying the worst eroded areas in the catchment, by erosion type, and to target and prioritise catchment rehabilitation and management strategies.

Within the Waiapu catchment it was considered important to separate those landforms with associated gully erosion from landforms where other types of erosion dominate because gullies generate the greatest proportion of the total sediment budget of the Waiapu River (Marden et al., 2008). Landforms with severe to extreme gully erosion made up 6.1% (10,502 ha) of the catchment; moderate gully made up 6.4% (11,143 ha); and slight gully erosion made up 9.2% (15,890 ha) with many of the largest and most active gullies being associated with the sheared and weakened lithologies of the East Coast Allochthon.

2.9.1.2 Impacts of erosion on land productivity and sustainability

Although we do not know with a great deal of certainty what proportion of the sediment yield is derived from erosion processes other than gullies, Harmsworth et al. (2002) estimated that 10-20% of the sediment is derived from landslide erosion. It is not known what proportion of the hillslopes in the catchment is affected by landslides. However, the area of land with potential erosion severity of 3 or greater remaining in grassland or cropland was 28,599 ha in 2008. Despite the lack of work on landslides and their effect on soils and productivity in the Waiapu catchment, some inferences can be made from soil evolution studies on similar lithologies in Wairarapa hill country further south. Landslides typically remove the upper 50-60 cm of the soil profile, exposing the subsoil beneath (Sparling et al., 2003). The exposed subsoils generally have higher bulk densities, higher clay contents, and lower organic matter content than uneroded topsoils (Vincent & Milne, 1990). Research on these eroded soils (Lambert et al., 1984; Rosser & Ross, 2011) has shown that pasture productivity on young landslide scars was ~20% of the pasture dry matter yields of uneroded surfaces and that scars revegetated rapidly over the first 20 years, reaching 70–80% of original production, but further recovery was very slow. They concluded that complete recovery of the soil profiles and pasture productivity might not occur in human life times. Lambert et al. (1984) attributed the lower pasture productivity on younger erosion scars to the physical properties of eroded soils, rather than to soil chemical factors. They concluded that reduced pasture production on erosion scars was most likely due to the dense, clay-rich substrates with high bulk densities that were exposed by erosion. These research findings have shown that there is a permanent reduction in soil depth and productivity on erosion scars and indicates that in the long-term, pastoral farming on steeper slopes underlain by poorly consolidated parent materials may become unsustainable (Rosser & Ross, 2011). The findings pertain only to those areas in the Waiapu catchment that are affected by shallow landslide erosion and not to areas affected by gullies, as gullies remove the entire soil profile and afforestation is the only practical option for stabilising them (Marden et al., 2005, 2008). We are unable to evaluate potential production losses for the Waiapu because we do not have the data required.

2.9.1.3 Causes & controls of erosion

Erosion in the Waiapu catchment is considered extreme because of the following contributing factors:

1. The widespread removal and burning of natural forest and scrub between 80 and 100 years ago.
2. Unstable underlying rocks resulting from extensive folding and faulting.
3. The high incidence of successive, large magnitude, storm events, particularly since forest removal.

The Gisborne–East Coast region is prone to intense rainstorm events (Tomlinson, 1980; Coulter & Hessell, 1980; Glade, 1998), and the landscape is a complex mosaic of fragile rocks and soils. Since deforestation there has been a dramatic acceleration in erosion with much of this being associated with large storm events. Gullies and landslides are now prevalent, particularly in areas of pastoral land, but their occurrence has also increased in areas of natural forest in recent years (Parkner et al., 2007).

2.9.1.4 Gully erosion

Gullies were described by Betts & DeRose (1999) as areas of actively eroding bare ground that were contiguous with the channels that drained them, and include gullies that are formed by both fluvial incision and mass movement. Based on written accounts of gully erosion in the upper Waipaoa catchment (Allsop, 1973; Gage & Black, 1979), it is likely that gully initiation occurred within a decade or two of the clear-cutting of natural forest (Marden et al., 2008) because removal of the forest cover lowers the topographic threshold for gully development (Parkner et al., 2006). Early aerial photography from 1939-1957, shows that gullies were absent from steepland areas that remained in natural forest, and suggest that gullies were minimal in forested areas prior to forest clearance (Marden et al., 2011).

The most significant period of gully development occurred from the 1940s-1960s when most of the catchment was under pasture, and gully development was exacerbated by major floods in 1938 and 1948, followed by a succession of heavy rainfall events in the late 1950s and early 1960s (Marden et al., 2008). Once initiated, gullies rapidly became entrenched with steep sides showing evidence of repeated slumping (Marden et al., 2011). The extent of gully erosion peaked in the 1970s, a decade after gully planting began, and about the time those early gully plantings achieved canopy closure and began to stabilise afforested gullies (Marden et al., 2008).

In the Wereaamaia catchment Parkner et al. (2006) identified phases of gully expansion from 1939-1957, inactivity 1957-1984, and a second phase of expansion (1984-1988), followed by inactivity between 1988-2003. Betts & DeRose (1999) also found the same pattern of overall gully development in the adjacent Waipaoa catchment, with an expansion phase between 1939 and 1958, and a phase of stabilisation (largely as a result of afforestation) between 1958 and 1992 (DeRose et al., 1998; Betts & DeRose, 1999; Marden et al., 2005). Research from the adjacent Waipaoa catchment (Marden et al., 2005) has shown that without a forest cover, not all gullies form at the same time or develop at the same rate, and the time required to shut-down a gully is highly variable. The result is gullies at different stages of development across the landscape (Page et al., 2008).

Much of the focus of erosion studies in the Waiapu catchment to date has been on gullies. The Waiapu catchment has the highest incidence of gullies in the East Coast region (Marden et al., 2008). In 1997, there were 976 active gullies with a combined area of 3,920 ha (39.2 km^2) (Marden et al., 2008). Active gullies continue to form in response to major storm events, and occur in seven major lithological formations (Mokoiwi Formation, Tinui Group, Whangai Formation (eastern facies), Mangatu Group, Waipawa Black Shale Formation, Tapuaeroa Formation, Melange). Gully development and orientation is influenced by major faults, joint patterns, bedding, and fold structures that predispose bedrock to mass movement failure (Parkner et al., 2007). As in the adjacent Waipaoa River, gully distribution and type is strongly influenced by slope physiography, which reflects the underlying geology (Marden et al., 2005; Parkner et al., 2007). The number of gullies and the area of land affected by gullying in each sub-catchment are listed in Table 2.8.

Table 2.8. Number and area of gullies in each sub-catchment as at 2008 (data supplied by Landcare Research).

Sub-catchment	No. of gullies	Gully area (ha)
Tapuaeroa	231	1325.1
Upper Mata	203	803.5
Raparaparirki	43	364.8
Mangaoporo	45	309.2
Waitahaia	73	225.5
Mangapoi	31	195.5
Lower Mata	50	147.5
Ihungia	16	80.0
Makarika	24	77.0
Mangawhairiki	14	57.6
Waiapu (Ruatoria)	14	37.9
Poroporo	7	29.0
Maraehara	12	23.9
Waingakia	8	14.2
Weraamaia	1	5.0
Waiapu (whole catchment)	683	3072.7

Most of the larger gully systems in the East Coast region are fluvio-mass movement gullies or gully complexes (Figure 2.7), because mass-movement processes play a major role in their enlargement compared to incision in classical gully formation by fluvial processes (Parkner et al., 2006). In the first stage of gully complex evolution, incipient, linear gullies gradually develop over-steepened sidewalls, which in turn initiate deep-seated mass movements (Betts et al., 2003). Linear gullies occupy topographically convergent areas in zero-order (unchannelled) basins, whereas larger amphitheatre-like gully complexes extend over virtually their entire catchment (DeRose et al., 1998). Mass-movement erosion accounted for almost 90% of the generated sediment for an 8 ha gully complex in the Tapuaeroa sub-catchment over a one-year period (Betts et al., 2003). Some evidence suggests that gullies are initiated at the sites of mass movements and this notion is supported by some of the gullies studied by Parkner et al. (2006). The term mass movement refers to any erosion type where material moves down slope as a more-or-less coherent mass under the influence of gravity.

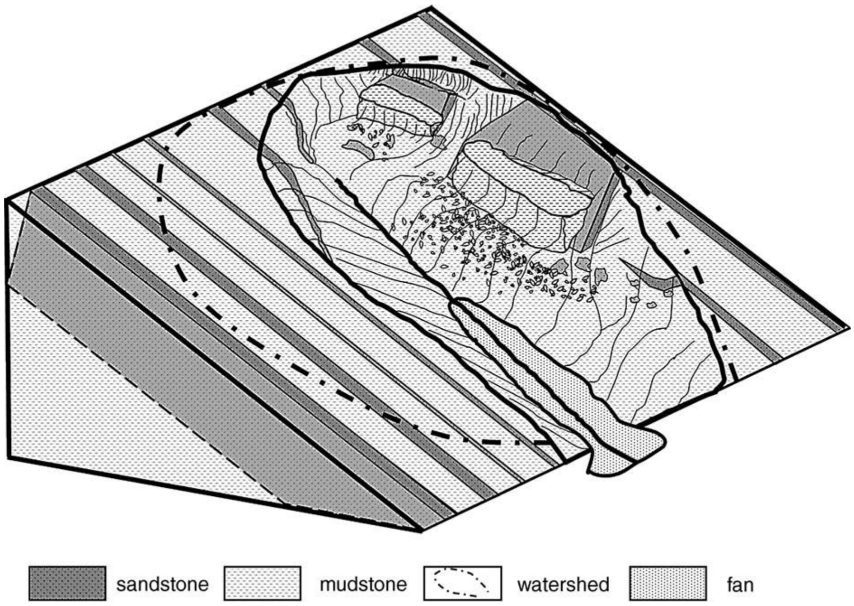


Figure 2.7. Sketch of an idealized gully complex (reproduced from Parkner et al., 2007).

Long-term studies on gully erosion have been carried out on Gisborne–East Coast landform terrains similar to those in the Waiapu catchment. Studies by DeRose et al. (1998) on gully erosion in the Mangatu Forest, and a similar study in the nearby Waingaromia sub-catchment (Betts & DeRose, 1999; Betts et al., 2003) used sequential high-resolution digital elevation models (DEMs) to identify relationships between gully area and long-term (1939–1958 and 1958–1992) sediment yield. This technique made it possible to estimate the average sediment yield of a gully on the basis of its area as measured from orthorectified aerial photographs.

Betts et al. (2003) further developed these techniques using DEMs and high-resolution aerial photographs in a sub-catchment of the Tapuaeroa catchment (see Figure 2.1). This work focussed on a single ~8 ha gully (Figure 2.8) to better understand how gully erosion processes and sediment yield relate to short-term or storm rainfalls. Orthorectified images of a gully were used at different dates to show vertical elevation changes between 1999 and 2001. Sequential DEMs were constructed at 50-cm resolution, covering a 13-month period of near-average rainfall with no extreme events. Results indicate ~5300 ± 1300 m^3 of sediment was lost from the gully, and ~630 ± 150 m^3 was excavated from the debris fan at the base of the gully.

Figure 2.8. Oblique photograph of an 8 ha gully complex in the Mangawhairiki sub-catchment (Tapuaeroa catchment). Note the evidence of mass movements around the periphery in the upper section of the gully complex. Photo by Harley Betts (reproduced from Parkner et al., 2006).

Parkner et al. (2006) identified topographic thresholds for gully initiation based on catchment area and slope (Figure 2.9), which can be used to aid identification of gully prone areas under different vegetation types. The graph shows that threshold values for gullies to develop under forest are greater than for gullies under pasture. After conversion to pasture the threshold decreases drastically, as a reduction in vegetation biomass reduces resistance to concentrated flow, and increases sensitivity to relatively small storms and changes to the intensity of rainfall and runoff (Parkner et al., 2006). With subsequent reversion to scrub, the threshold for gully initiation slowly increased and returned to a similar level to that under natural forest.

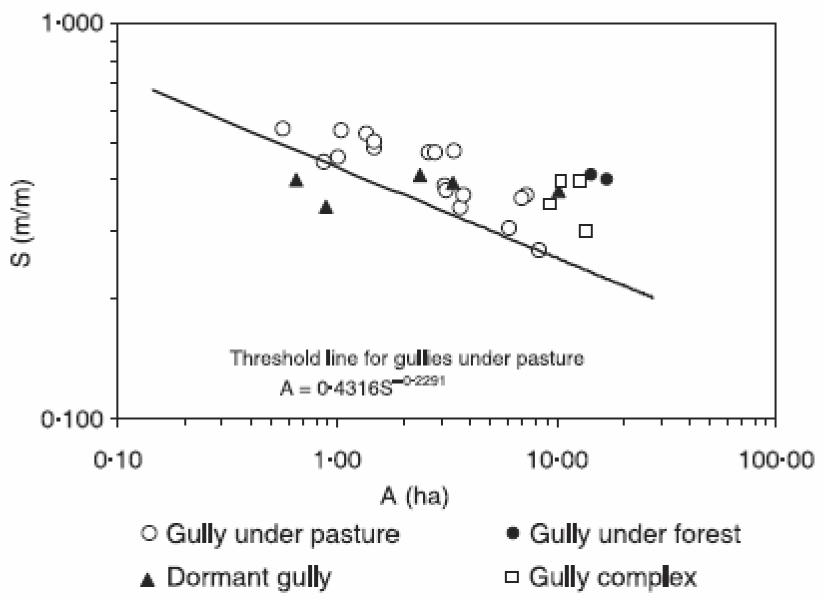


Figure 2.9. Relationship between slope and drainage area for gullies under pasture, gullies under forest, dormant gullies, and gully complexes as well as a threshold line for gully development under pasture (reproduced from Parkner et al., 2006).

Using GIS analysis of a database of gullies derived from interpretation of orthorectified aerial photographs (dated 1957 and 1997) and DEMs of 37 individual gullies, Marden et al. (2008) determined that for gullies that developed in Cretaceous terrain, the rate of increase in gully area was accompanied by an increase in gully depth. However, there was no such relationship for gullies developed in Tertiary terrain. Gullies developed in Tertiary terrain tend to be dominated by fluvial processes and typically maintain a narrow, linear shape as the gully deepens. In contrast, gullies developed in Cretaceous terrain – where the underlying bedrock is typically structurally weak and fault crushed – enlarge both by fluvial and mass movement processes, resulting in a closer relationship between gully area and depth, and a faster rate of incision. As a consequence, gullies formed in Cretaceous terrain typically form larger amphitheatre-like gullies (see Figure 2.8).

Gully erosion continues to worsen on pasture land. A recent comparison of gullies in the Raparapaririki catchment from 1957 to 2003 showed that the total area of gullies increased from 142 to 267 ha, and most of the gullies deepened considerably (Marden, 2004). This study concluded that while the rate of sediment supply to the channel may be expected to diminish in the longer term, the current source areas (in the headwaters of the Tapuaeroa) have yet to be exhausted of material. Based on the rate of gully expansion in the pasture areas in the Mangapoi and Mangawhairiki sub-catchments and in the absence of suitable planting intervention it was estimated that productive pasture land would be lost at a rate of 2.5-4% per year over a timeframe of 2-4 decades. Gullies in the

Mangapoi and Mangawhairiki sub-catchments already occupy 9.8% and 7.8%, respectively, of the land area currently in pasture (Marden, 2004).

2.9.1.5 Sediment production from gullies

Gullies are a chronic source of sediment. Once established they show little evidence of an erosion threshold (in terms of a minimum storm rainfall required for gullies to supply sediment to streams). Erosion thresholds for landsliding are much higher, leading to large, but less frequent sediment inputs (Page et al., 2008).

Using the database of gullies mapped for 1957 and 1997, and a degradation rate based on DEMs of gullies at different stages of development, Marden et al. (2008, 2011) calculated sediment production rates for the 40 year period. The rate of sediment production from gullies in the Waiapu catchment, irrespective of land cover, was 9,548 t/km^2/yr for the period 1957-1997 (Marden et al., 2008). This rate is approximately 3.5 times greater than that in the Waipaoa catchment over the same period (2,880 t/km^2/yr). Total sediment production from Waiapu gullies was 676 Mt, equivalent to 17 Mt/yr. Gullies are the single largest sediment source in the Waiapu catchment and produce approximately 49% of the total sediment yield of the Waiapu River, from just 2.4% of the hill country terrains (Marden et al., 2008). Gullies in Cretaceous terrain contributed 76% of the gully sediment yield (which is equivalent to 37% of the total catchment sediment yield). Sediment production from gullies in Tertiary terrain contributed 12% of the average annual sediment load of the Waiapu River.

2.9.1.6 Other erosion processes

While gullies supply approximately 49% of the annual sediment yield, half of the sediment yield is unaccounted for. Based on other studies such as the Waipaoa (Marutani et al., 2005; Page et al., 2001b;) and Weraamaia catchment research (Page et al., 2001a, Kasai et al., 2005), together with GIS analysis of erosion type, land system, and rock type, sediment characterisation, Land Use Capability (LUC) and landform mapping, and general field observations, Harmsworth et al., (2002) hypothesised a sediment budget for the Waiapu catchment (Table 2.9). Although this sediment budget needs to be refined and updated it provides an assessment of the approximate contribution of sediment to the river from each major erosion type in the catchment. Other significant sources of sediment to the river system include landslides and slumps, stream bank erosion, riparian slips, sheet erosion, and earthflows. Notably, up to 40% of the sediment entering the channel during flood events may be deposited and stored in the river channel or on the floodplain and is available for transport in subsequent flood events. This notion is further supported by the persistence of aggradation of the river beds in most of the higher order river channels.

Table 2.9. Hypothesised sediment budget for the Waiapu catchment (from Harmsworth et al., 2002).

Sediment sources	% contribution of total sediment yield
Channel deposition	0–40%
Sheet	5–10%
Streambank	5–10%
Riparian slip	5–10%
Soil slip (landslide)	10–20%
Slump	3%
Debris avalanche	3%
Earthflow	4%
Gully	>50%
Total	100%

2.9.1.7 Main points

- Gullies were largely absent in steepland areas in natural forest, prior to forest removal.
- Deforestation initiated a phase of accelerated erosion, starting with landslides on the newly deforested slopes, and the reactivation of earthflows and gullies.
- Gully initiation occurred within a decade or two following clearance of the natural forest.
- Removal of the forest cover lowers the topographic threshold for gully development by lowering the resistance to concentrated flow, and increasing the sensitivity to relatively small storms.
- The most significant period of gully development was from the 1940s to 1960s, and gully area peaked in the 1970s.
- Gully expansion has been episodic, with phases of gully expansion, inactivity and stabilisation, largely related to the timing of afforestation and canopy closure, and storm events.
- The Waiapu catchment has the highest incidence of gullies in the East Coast region and New Zealand.
- Most gullies are fluvio-mass movement complexes, because sediment is eroded by both fluvial incision and mass movement processes.
- Gullies in Cretaceous terrain typically form amphitheatre-like gullies because mass movements play a greater role in the more highly deformed rocks, while gullies in tertiary terrain are typically linear in shape because their development is dominated by fluvial incision.

- The topographic threshold for gully initiation is greater under forest than under pasture. After conversion to pasture, the threshold decreases drastically (because resistance to concentrated flow is reduced), and sensitivity to changes in rainfall and runoff increases.
- Gully erosion occurred under natural forest following Cyclone Bola in 1988, where storm rainfall was likely between 700 and 900 mm. The gullies decreased in size from 21 ha to 13 ha by 1997 due to regeneration by native species. Under normal climatic conditions, natural forest can protect against gully development and accelerate the stabilisation of gullies.
- Gullies are a chronic source of sediment; the dominance of mass movement erosion over surface processes means that the relationship between rainfall events and gully response is weak. Mass movements can continue for long periods in the absence of rainfall.
- Gullies in Cretaceous terrain produced 76% of the gully-derived sediment whereas gullies in Tertiary terrain produced 24% of the gully-derived sediment.
- Gully erosion is the single most significant sediment source in the Waiapu catchment and produces 49% of the total annual sediment yield. The remaining of the sediment yield is derived from landslides, earthflows, stream bank erosion, fluvial incision, and sediment stored in rivers and streams.
- An estimated 10-20% of the sediment yield is derived from landslide erosion. Landslides typically remove the upper 50-60 cm of the soil profile, exposing the subsoil beneath. Research on eroded soils on similar lithologies in Wairarapa hill country further south has shown that soil depths and pasture productivity on landslide scars was permanently reduced compared to uneroded soils. Reduced pasture production on erosion scars was most likely due to the dense, clay-rich substrates with high bulk densities that were exposed by erosion. These research findings indicate that in the long-term, pastoral farming on steeper slopes underlain by poorly consolidated parent materials may become unsustainable.

2.9.2 Fluvial response to changes in sediment supply from hillslopes

The huge volume of sediment generated by gullies and other mass movement processes following deforestation has led to rapid aggradation in the main stem and tributaries of the Waiapu River. Aggradation in the last ~100 has overwhelmed the background – climatically and tectonically controlled – incision of the fluvial network (Litchfield & Berryman, 2006). The processes of river aggradation and incision are primarily driven by sediment load and water discharge. Aggradation occurs where the sediment load (especially coarse sediment) exceeds the rivers capacity to transport it, while a sediment load below transport capacity will result in incision. However, the nature and rate of channel response to changes in sediment supply are more difficult to forecast, being influenced by many, often catchment-specific, factors. Upland tributaries are more sensitive to changes in sediment supply than lowland reaches because upland sediment sources are more closely connected with channels, transport events have a higher magnitude and frequency, and because there are fewer sediment stores along the fluvial network. In the case of coarse components of the sediment load there can be significant lags of decades to centuries following upstream channel incision before the sediments in headwater channels are flushed through downstream reaches. Despite sediment yields that are high by world standards, (often an order of magnitude greater), the response of the Waiapu and other East Coast rivers to changes in sediment supply is rapid.

Aggradation and channel widening processes are affecting the Waiapu floodplain, mainly through inundation and bank erosion, together with many meander bends undermining adjacent hillsides (Page et al., 2008). Significant examples are given in Table 2.10.

Table 2.10. Sediment-related impacts affecting infrastructure on the main stems of the Waiapu/Mata Rivers.

Location	Impact	Mitigation measures
Matahiia Rd	Bank erosion and sedimentation from the Mata River	-
Ruatoria township /Piggery Rd	Bank erosion and river bed migration	Downstream of SH 35 bridge, three dolosse (groynes) constructed 2010/2011 to divert Waiapu River away from Ruatoria (project ongoing)
SH 35 bridge Ruatoria	Bank erosion	Right bank abutment, two large sheet pile groynes constructed 1950s/1960s to stabilise bank
Waiomatatini Rd opposite Mangaoporo River	Bank erosion and hill slope instability	Rock groynes constructed by GDC c. 2003-2009 to protect road at bottom of Kaiinanga hill
Waiomatatini Rd near Waiomatatini hill	Hillslope instability	Steel and rock groynes constructed in 1980s by Waiapu County to protect road and stabilise toe of hill, and again in 1990 by GDC, hillside above road planted in pines
SH35 at Pepere's corner 4 km upstream of Tikitiki	Bank erosion	Major rock riprap bank protection works to protect highway, c. 2005
SH 35 2 km upstream of Tikitiki	Bank erosion	Major rock groynes to protect highway, early 2000s

Few large storms have affected the catchment since Cyclone Bola in 1988, and with continued afforestation, a reduction in sediment supply from hill slopes has resulted in incision in a number of upper tributary reaches. Nevertheless, vast quantities of sediment remain stored in the stream channel network as bedload, ensuring that as this phase of incision progresses, the sediment supply to the lower reaches and the floodplain will remain high (Page et al., 2008). Aggradation of rivers and streams is a major threat to the Waiapu floodplain (which is unprotected by stopbanks/levees), roads, and bridges. In addition, the town of Ruatoria and several small community settlements are located near or adjacent to this rapidly aggrading floodplain. Aggradation has also impacted adversely on river health and ecology (see Section 9.4.1).

GDC has monitored river and stream bed levels, through repeated surveys of cross-sections of selected reaches of the Waiapu River downstream of the confluence of the Mata and Tapuaeroa Rivers, and in 16 sub-catchments (Table 2.11). These data, together with case studies in the Raparapaririki, Mangapoi, and Mangawhairiki catchments (Sections 9.2.2, 9.2.3) (Peacock and Marden, 2004; Liébault et al., 2005; Peacock 2010), and the Weraamaia catchment (Section 9.2.4) (Kasai et al., 2005; Kasai 2006; Parkner et al., 2006), that link the supply of sediment from hillslopes with the transfer of that sediment through the channel network, provide indications of the lag-time between increases/decreases in sediment supply from hillslopes and aggradation/incision of river channels in headwater catchments. However, lag-times in the middle and lower reaches of the Waiapu River will be much longer and more difficult to estimate, given the more complex spatial and temporal distribution of vegetation in relation to erosion-prone terrain and the extensive channel network.

Table 2.11. Summary of Gisborne District Council rivers/streams bed level surveys (as at November 2011).

River/stream	Catchment area (km^2)	No. x-sections	Survey start date	Survey end date	Survey years	Surveyed length (km)
Waiapu	1734†	7	1958	2007	49	18.4
Mata		4	1958	2007	49	0.1
Tapuaeroa		6	1958	2007	49	17.2
Raparapaririki	35.1	9	1974	2010	36	3.3
Wairongomai	36*	7	1979	2004	25	3.7
Mangaraukokore	29*	9	1977	1993	16	3.6
Poroporo		6	1958	2004	46	18.5
Mangaoporo		6	1958	2007	49	11.1
Mangapoi	14.4	5	2004	2010	6	0.6
Mangawhairiki	4.7	5	1979	2010	31	1.5
Maraehara		3	1958	2003	45	5.3
Kopuaroa		2	1958	2002	44	2.0
Makatote		3	1958	2002	44	6.8
Paoruku		1	1958	1998	40	n/a
Makarika		2	1958	2002	44	n/a
Mangaharei		4	1979	2006	27	0.6
Manutahi		5	1979	2000	21	0.4

* Catchment area approximate.

† Total catchment area calculated in his study was 1738 km^2.

2.9.2.1 Cross-section surveys

Of the 17 sites monitored by GDC, the 7 sites described below have sufficient length of record and number of cross-sections to identify trends. The following information is taken from a report evaluating all cross-section surveys prepared for this review (Peacock, 2011). Changes to the following four parameters derived from these surveys are indicative of trends and rates of aggradation/incision; mean bed levels, rate of change of mean bed levels, active bed widths, and volumes of bed material deposited.

Mean bed levels (MBL‘s) for a specified river or stream give an indication only at specific cross-sections of whether a river/stream is aggrading or incising. However, this parameter can be improved if two or more adjacent MBL‘s are averaged over a specific reach of river.

Rate of change of mean bed levels not only shows whether a river or stream is aggrading or incising, but also gives information on the rate at which the bed is rising or falling, and provides information about the speed of response to a sudden input of bed load material from upstream.

Active bed width is also useful but does not always follow the aggradation/incision trends shown by MBL results. This may be for two reasons, firstly it can be difficult for a surveyor to define the active bed limits, and secondly a river can be aggrading by deposition of bed load material near the centre of the active bed, but vegetation encroachment at one or both sides can make the active channel narrower. Thus MBL calculations may show that the river bed is aggrading while active bed width measurements may show the river appears to be incising. Hence, active bed widths are only a useful measure if the active bed is changing substantially between surveys, and even then these measurements need to be treated with caution.

Volume of bed load material deposited is ‘normalised‗both spatially and temporally as cubic metres per lineal metre per year (m^3/m/yr). This means that valid comparisons can be made between rivers as to what proportion of the deposited bed load is being stored in the respective rivers over the same time period.

Waiapu River

There are seven cross-sections in the Waiapu River downstream of the confluence of the Mata/Tapuaeroa Rivers that have been surveyed from 1958 to 2007. Three of these cross-sections were suitable for analysis for this project (Peacock, 2011). Over the 49 year period, the average aggradation rate at Ruatoria has been approximately 19 mm/yr, reducing to only 3 mm/yr near the confluence with the Poroporo River. Table 2.12 shows the three benchmarking parameters; mean bed level, rate of change of mean bed level, and active bed width at the three cross-sections considered to provide valid bed level data.

Table 2.12. Waiapu River cross-section analysis results.

Location[1]	Benchmarking Parameter	Circa 1969	Immediate pre-Bola	Immediate post-Bola	Current 2007
Ruatoria 20,300 m	MBL (mamsl)	41.60[2]	42.23[4]	42.44[6]	42.11[8]
	MBL rate of change (mm/yr)	+14[3]	+189[5]	-94[7]	+115[9]
	Active width m	280	286	296	294
Ruatoria 13,680 m	MBL (mamsl)	25.51	25.90	26.12	26.43
	MBL rate of change (mm/yr)	+75	+42	-31	+38
	Active width m	197	198	215	233
Tikitiki 4870 m	MBL (mamsl)	5.73	5.75	5.83	5.89
	MBL rate of change (mm/yr)	+34	-32	-13	+96
	Active width m	882	915	930	941

[1] The location refers to the distance (in m) upstream from the river mouth or confluence.

[2] 1969 MBL‘s are interpolated between 1967 and 1972 surveys.

[3] Rate of change of MBL‘s are for the period 1967 to 1972.

[4] “Pre-Bola” MBL‘s are for 1986, except at the 20,300 m cross-section which is from the 1982 survey.

[5] “Pre-Bola” rates of change of MBL are for the period 1982 to 1986; except for the 20,300 m cross-section which is for 1979 to 1982.

[6] “Post-Bola” MBL‘s are for 1989.

[7] Post-Bola rates of change of MBL are for the period 1989 to 1998, except at 20,300 m which is for 1989 to 2005.

[8] “Current” MBL‘s are for 2007.

[9] “Current” rates of change of MBL are for the period 2005 to 2007.

Overall trends:

- Moderate but fluctuating aggradation, with incision during Cyclone Bola.
- Rapid increase in bed width at both Ruatoria and Tikitiki. Active channel width has increased by 14 m at Ruatoria, 36 m at 13.68 km, and 59 m at Tikitiki from 1969 to 2007.

Tapuaeroa River

Six cross-sections have been surveyed between 1958 and 2007 in the Tapuaeroa River. Cross-sections in the lower reaches of the Tapuaeroa River record changes in sediment yield from the Raparapaririki, Mangapoi, Mangawhairiki, Wairongomai, and Mokoiwi Streams. Table 2.13 shows benchmarking parameters and the data for two of the six cross-sections; the most upstream one at 19,500 m, and the most downstream one at 2,270 m upstream of the confluence with the Waiapu River. Data for all six cross-sections is shown in Appendix 3.1, together with explanatory notes.

The Tapuaeroa River was incising at both the upstream and downstream surveyed cross-sections circa 1969, at the (relatively slow) rate of 60 and 21 mm/yr respectively, and this incision continued at about the same rate at the upstream section from 1982 to 1986. However, in the post-Bola period of 1988 to 1993, there was rapid aggradation of the river bed at 172 mm/yr at the upstream cross-section. This rapid aggradation is thought to have been due to bed load input from Cyclone Bola, and a delayed response from the major storm in December 1980 and Cyclone Bernie in 1982 (Peacock, 2011). The effects of this sudden input of bed load material has not yet been translated as far downstream as the 2,270 m cross-section as the river bed continued to incise here at least until 1998. In 2007, the Tapuaeroa River was rapidly aggrading at the upstream end. The Tapuaeroa shows no signs of recovery yet from Cyclone Bola, some 19 years after the event, and it may be decades yet before this river begins to incise and shows incision over its full length.

Table 2.13. Tapuaeroa River cross-section analysis results.

Cross-section	Bench marking parameters	Circa 1969	Immediate Pre- Bola	Immediate Post-Bola	"Current" (2007)
19,500 m	Mean bed level (m)	187.06	186.88	188.09	n/a
	Change in MBL (mm/yr)	-60	-68	+172	n/a
	Active bed width (m)	97	101	101	n/a
2,270 m	Mean bed level (m)	69.57	69.59	69.57	70.03
	Change in MBL (mm/yr)	-21	0	-28	+52
	Active bed width (m)	422	424	430	437

Overall trends:

- Upstream reaches were incising prior to 1987, then rapid aggradation from 1988-1993 due to Cyclone Bola and two earlier storms (in 1980 and 1982).
- Downstream reaches, which were incising c. 1969, showed a lag in response to this input of sediment by continuing to incise until at least 1998, and only switching to aggradation by 2007.

- Active bed widths have been gradually increasing in the lower reaches.

Mangaoporo River

Six cross-sections in the Mangaoporo River have been surveyed between 1958 and 2007. The Mangaoporo River was aggrading rapidly (166 mm/yr) over the pre-Bola period at the most upstream cross-section, but only gradually after the Bola storm (Table 2.14).

Table 2.14. Mangaoporo River cross-section analysis results.

Cross-section	Bench marking parameters	Circa 1969	Immediate Pre- Bola	Immediate Post-Bola	"Current" (2007)
12,530 m	Mean bed level (m)	170.40	172.18	172.24	n/a
	Change in MBL (mm/yr)	+21	+166	+22	n/a
	Active bed width (m)	170	182	220	n/a
1,450 m	Mean bed level (m)	51.24	51.80	51.96	52.21
	Change in MBL (mm/yr)	+39	-11	-1	-5
	Active bed width (m)	297	297	297	290

Over the period 1969 to 2007, the upstream cross-sections aggraded at a rate of about 40 to 60 mm/yr, and at a rate of about 20 to 25 mm/yr at the downstream sections (Table 2.14 and Appendix 3.3). Over the recent period from 2003 to 2007, there are signs of incision at the two downstream cross-sections.

Unlike the Tapaueroa River and its tributaries, the Mangaoporo River appears not to have been greatly affected by Cyclone Bola, and the active bed width has remained relatively stable. Therefore, there are significant differences in the responses of the two river systems which should be monitored.

Overall trends:

- Aggraded rapidly pre-Bola, and aggraded only gradually post-Bola, in upstream reaches. There are signs of slight incision in lower reaches between 2003 and 2007.
- Active bed width is increasing in the upper reaches, and is stable in downstream reaches.

Raparapaririki Stream

Nine cross sections extending 3.4 km up the Raparapaririki Stream (‗The Rip‗) have been surveyed regularly between 1974 and 2010. Table 2.15 shows the results of cross-section analysis for two of the nine cross-sections; the most upstream one at 3,379 m, and the most downstream one at 100 m. Data for all nine cross-sections is shown in Appendix 3.2, together with explanatory notes.

It is likely that the rapid aggradation (543 mm/yr) at the upstream cross-section prior to 1987 (see Table 2.15), was in response to sediment delivered to the channel from a heavy rainfall event in December 1980, (and to a lesser extent the Cyclone Bernie event in April 1982) which caused extensive damage in the Raukumara Ranges (Phillips; 1988).

Table 2.15. Raparapaririki River cross-section analysis results.

Cross-section or reach	Bench marking parameters	Circa 1969	Pre- Bola (1987)	Post Bola	"Current" (2007)
3,379 m	Mean bed level (m)	-	248.13	-	281.10
	Change in MBL (mm/yr)	-	543	2070	-48
	Active bed width (m)	-	33	-	210
2,915 to 3,379 m	Volume deposited (m3/m/yr)	-	5.9	355	-
100 m	Mean bed level (m)	-	188.36	-	196.21
	Change in MBL (mm/yr)	-	189	398	13
	Active bed width (m)	-	140	-	193
100 to 668 m	Volume deposited (m3/m/yr)	-	13	51	29

Cyclone Bola caused massive erosion under natural forest in the headwaters of the Raparapaririki Stream and the channel was swamped with sediment. At the most upstream cross-section the stream bed aggraded at an annual rate in excess of 2 m/yr (Table 2.15) between 1987 and 2003. This is an extreme rate of aggradation not only for New Zealand rivers, but worldwide.

By contrast, the annual rates of aggradation have been much more modest at the most downstream cross-section near the confluence with the Tapuaeroa River. However, an annual aggradation rate of 398 mm/yr was measured for the six year period following Cyclone Bola.

Overall trends:

- Generally incising in 1970s and 1980s.
- Rapid aggradation in the upper reaches prior to 1987 due to storms in 1980 and 1982.
- Massive aggradation following Cyclone Bola, especially in the upstream reaches.
- Between 2007 and 2010, incision occurred in the upper reaches and aggradation slowed in the lower reaches.
- Active channel width increased dramatically at all cross sections over the period of record. At some cross-sections, the active channel width increased by 300-600%.

Mangapoi Stream

There are five cross sections in the Mangapoi Stream that were surveyed from 2004 to 2010 (Table 2.16). Prior to 2004, there was only one cross-section (at the bridge), which showed an average aggradation rate of 210 mm/yr. However, since November 2004, the stream bed has generally incised. The average drop in mean bed level is 169 mm, or 31 mm/yr. As at 2004, about half of the total eroded area within this catchment occurred within the combined area of natural forest and reverting scrub (in the upper catchment), with the remainder on farmland in the lower reaches.

Table 2.16. Mangapoi and Mangawhairiki cross-section analysis results.

Cross-section or reach	Bench marking parameters	Immediate Pre- Bola (1987)	Post-Bola	"Current" (2007)
Mangapoi; 713 m	Mean bed level (m)	-	-	187.08
	Change in MBL (mm/yr)	-	-207 (2004-07)	+43 (2007-10)
	Active bed width (m)	-	-	106.7
Mangapoi; 146 m	Mean bed level (m)	-	-	171.69
	Change in MBL (mm/yr)	-	+45 (2004-07)	-131 (2007-10)
	Active bed width (m)	-	-	101.7
Mangawhairiki; 1,258 m	Mean bed level (m)	205.74	-	204.68
	Change in MBL (mm/yr)	-92 (1984-87)	+63 (1987-04)	-111 (2007-10)
	Active bed width (m)	31.3	-	35.2
Mangawhairiki; 154 m	Mean bed level (m)	144.35	-	144.35
	Change in MBL (mm/yr)	-281 (1984-87)	-2 (1987-04)	+18 (2007-10)
	Active bed width (m)	72.1	n/a	144.6

Overall trends:

- Cross-section data only exists for the period 2004 to 2010.
- Aggrading prior to late 2004, and incising since in the lower reaches. The upper reaches are still aggrading at 43 mm/yr.
- No information available on active bed width changes through time.

Mangawhairiki Stream

There are five cross-sections in the Mangawhairiki Stream surveyed from 1974 to 2010 (Table 2.16).

Overall trends:

- Aggrading in late 1970s and 1980s (from 1980 storm and Cyclone Bola).
- From 2007 to 2010 incising in upstream reaches and still aggrading in the downstream reaches.

- Active bed width has remained relatively stable in the upstream reaches, but increased markedly (by 200 %) in the lower reaches.

Makarika Stream

The two cross-sections on the Makarika Stream are 3.5 km and 19 km respectively upstream of the confluence with the Mata River. From mean bed level data currently available, at the upstream cross-section (19 km), the stream bed has aggraded at an average rate of 30 mm/yr from 1958 to 1988, and then incised at an average rate of 20 mm/yr up to the time of the last survey in 2002. The downstream cross-section (3.5 km) follows the same general pattern but delayed in time and with reduced aggradation/incision rates. Here the stream bed has aggraded at an average rate of 20 mm/yr from 1958 to 1994, and then incised at an average rate of 16 mm/yr up to the time of the last survey in 2002. Not all the surveys over this period have been analysed as yet, but it appears that Cyclone Bola has not had the marked effect on the deposition of bed load in the Makarika stream as it has in the Tapuaeroa and its tributaries.

Overall trends:

- Aggrading prior to Cyclone Bola, and incising since. Both aggradation and incision greatest in the upstream reach.

2.9.2.2 Case study 1: Raparapaririki catchment

This case study provides an example of the impact of a large magnitude rainfall event on naturally forested slopes in a medium-sized catchment.

Many rivers throughout the region have been aggrading as a result of deforestation. However, some headwater streams have been stable or incising where natural forest remains. One such stream was the Raparapaririki, a tributary of the Tapuaeroa River which is a major branch of the Waiapu River (Figure 2.10). It drains a 35-km^2 catchment, the upper ~74% of which is under natural forest cover. The remainder of the catchment, originally cleared for pasture in the late 1800s and early 1900s, is now under exotic forest. The exotic forest was planted in the early 1970s (true right bank) and in 2000 (true left bank) to control numerous linear gullies that had developed. The area of natural forest is underlain by alternating sandstone and mudstone of the Tikihore and Tapuwaeroa Formations, and the remainder by Mokoiwi Formation sandstone and mudstone (Mazengarb & Speden, 2000).

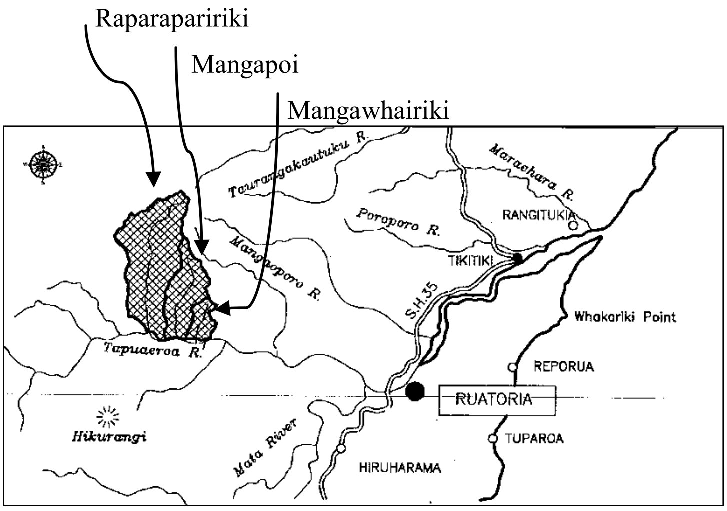


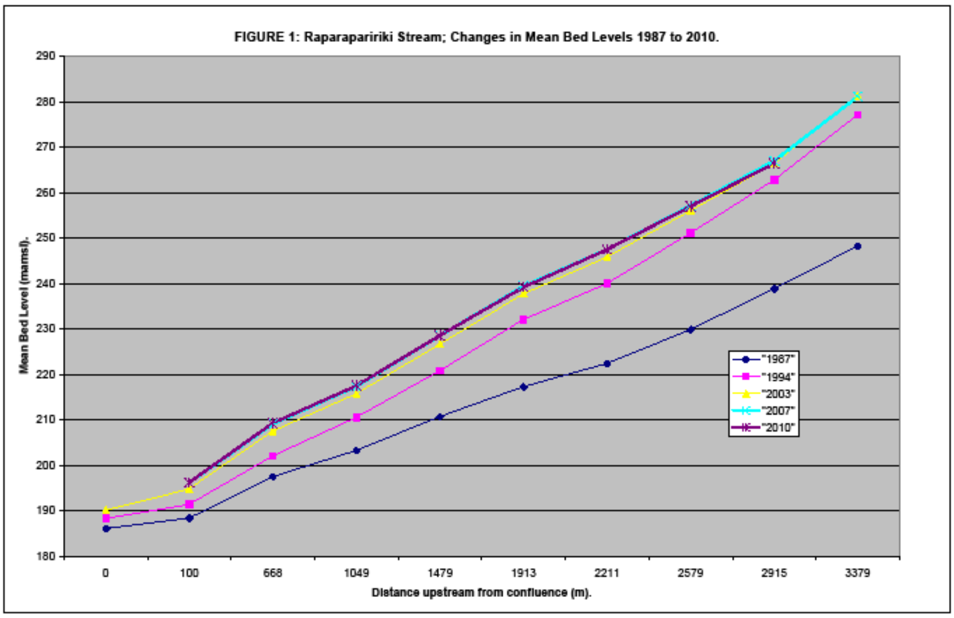
Figure 2.10. Location of the Raparapariririki, Mangapoi, and Mangawhairiki catchments (reproduced from Peacock & Marden, 2004).

In March 1988 Cyclone Bola, the largest magnitude storm event on record in the catchment, caused extreme erosion under the natural forest. Subsequent concerns by the District Council over the impact of channel aggradation on the road bridge across the Raparapariririki stream, and bridges across two other streams, has led to two reports on bed level changes and sediment sources within this catchment (Peacock & Marden, 2004; Peacock, 2010). Mean bed levels have been calculated at nine cross-sections for surveys in 1987, 1994, 2003, 2007, 2009, and 2010. Prior to Cyclone Bola the stream was incising at most cross-sections, leading to the exposure of supports on the road bridge (670 m upstream). At this time the channel was a steep bouldery mountain torrent with trout present.

Rainfall during the four days of Cyclone Bola (extrapolated from the nearest rain gauges), was likely to have been between 700 and 900 mm. In the headwaters of the catchment there was a 350% increase in the area of landslides and associated gullying (Liébault et al., 2005). The result was an immediate supply of gravel into the stream network due to the strong connectivity between erosion scars and channels. In places previously stable, vegetated terraces were buried by sediment. In excess of 87% of the eroded area in the catchment is now within the area of natural forest.

At the most upstream cross-section the stream bed aggraded 33.5 m between 1987 and 2004, at an average of 1.97 m y^{-1} (Peacock & Marden, 2004). A survey in October 1994 showed that the stream bed at the bridge had aggraded 4.5 m since 1987, and by June 1996 had reached the top of the deck, by which time a new bridge had been constructed 500 m downstream. Immediately downstream of the present bridge the bed had aggraded 7.2 m between 1987 and 2004, and the bed width had increased from 134 to 191 m. In the six years following Cyclone Bola, 4.4 x 10^6 m^3 of sediment accumulated in the 3.3-km-long reach upstream from the confluence with the Tapuaeroa River, and a further 2.6 x 10^6 m^3 of gravel accumulated in the succeeding nine-year period (Liébault et al., 2005). At the junction of the two rivers, aggradation in the Tapuaeroa River was half that of the Raparapaririki Stream, leading to a ―perching" of the Raparapaririki stream bed.

Since 1994 the rate of aggradation has progressively slowed (Figure 2.11) and between 2007 and 2010 aggradation at the lower end of the reach has been much slower (approximately 7 cm/yr at 668 m) and from 1,497 m upstream the stream has been incising. The maximum rate of incision is approximately 19 cm/yr at 2,195 m. It is probably even faster at the most upstream section (3,379 m), but no survey was done at this section in 2010.



Peacock D H Ltd;
Data courtesy of GDC;
28th June 2010.
Fig. 1
Rip_mbls_vols.xls

Figure 2.11. Mean bed levels for 1987, 1994, 2003, 2007, and 2010 in the Raparapaririki Stream (reproduced from Peacock, 2010).

Figure 2.12 is a graph showing the volume of bed load material deposited in the lower reaches of the Raparapaririki Stream (per lineal metre of stream bed per annum) for three successive seven year time spans (1987 to 1994, 1994 to 2003, 2003 to 2010). The graph very clearly shows how rapidly the deposition of bed load material has been reduced since 1994, especially at the most upstream reach where over 350 m^3/m/yr was deposited in the 1987 to 1994 period, some 80 m^3/m/yr in the period 1994 to 2003, and nil over the most recent period (2003 to 2010). Between 2007 and 2010 (not shown in Fig.

10) there has been a net incision upstream of reach 1,705 m. By contrast, at the most downstream reach the volume of bed load material deposited per lineal metre of channel per annum for the first period was about 50 m^3/m/yr; rising to 84 m^3/m/a for the period 1994 to 2003, then dropping back to 50 m^3/m/yr for the 2003 to 2010 period. Thus it can be seen that the bed load material is moved downstream in two 'waves_which represent bed load material from storms in 1980 and 1982, followed by material from the larger Cyclone Bola event.

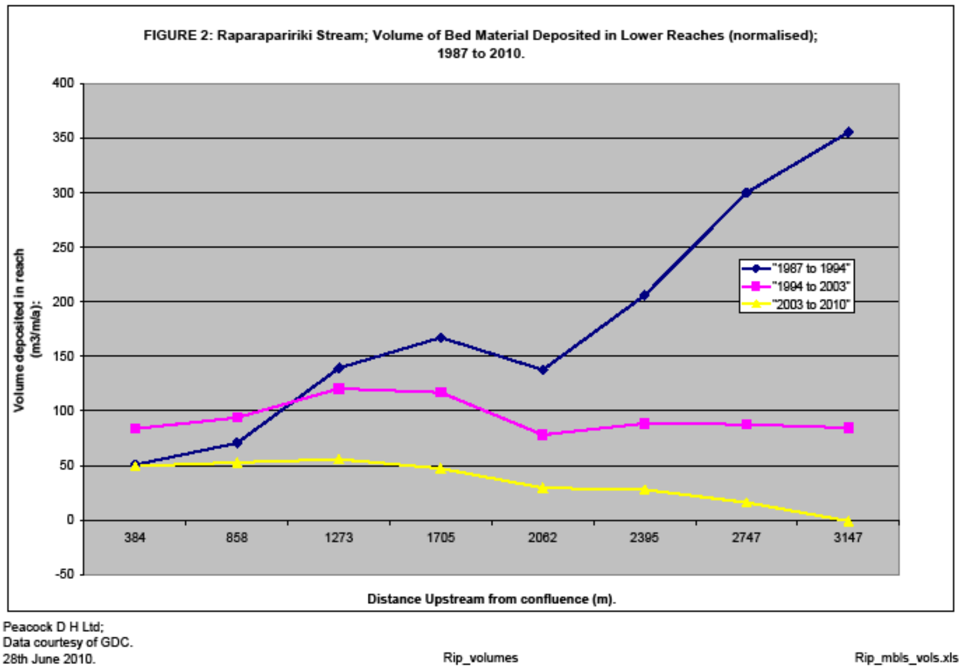


Figure 2.12. The volume of bed load material deposited in the lower reaches of the Raparapaririki Stream (per lineal metre of stream bed per annum) for three successive seven year time spans (reproduced from Peacock, 2010).

At the time of the 2004 report (Peacock & Marden, 2004), aggradation at the bridge site was expected to continue at ≥ 45 cm/yr for the next 5−10 years, followed by reduced aggradation. However, this high rate of aggradation has not eventuated; instead it has slowed markedly over the past three years to only 1.4 cm/yr. Downstream proceeding incision is now well underway, and is expected to continue into the future, unless another major storm re-activates or provides new sediment sources on the hill slopes. The present slow rate of aggradation at the bridge site is expected to slow even further, as the change from aggradation to incision proceeds downstream of the 1,497 m cross-section.

Land-use-driven changes in vegetation cover generally exert the most important control on erosion in New Zealand. However, this example illustrates that, given certain physical conditions (in this case tectonic setting, erodible rock type, and very steep slopes), forested landscapes are also highly sensitive to erosion during a large magnitude rainfall event, and once a threshold is exceeded, these landscapes are capable of generating volumes of sediment of the same order of magnitude as similar landscapes in pasture. The volumes of sediment generated are so great they have a sudden and ongoing impact on the stream network.

2.9.2.3 Case study 2: Mangapoi and Mangawhairiki catchments

This case study provides examples of gully development and sediment supply and transfer in response to rainfall in small catchments.

i. Mangapoi catchment

The Mangapoi catchment is next to the Raparapaririki catchment and the stream joins the Tapuaeroa River about 2 km downstream of the Raparapaririki confluence (see Figure 2.10). This catchment was also subjected to massive sediment inputs during Cyclone Bola. Rates of stream bed aggradation at the bridge site were 22 cm and 20 cm/yr for the periods 1984 to 1994 and 1994 to 2004 respectively (Peacock & Marden, 2004). Until 2004 there were no other cross-section sites. Five further cross sections were then established over a reach of some 700 m from the confluence with the Tapuaeroa River, and surveyed in 2004 (twice), 2007, 2009, and 2010 (Peacock, 2011). Over an 8 month period from March to November 2004, the average rise in mean bed level over the 700 m reach was 18.8 cm, or 28.2 cm/yr. However, since November 2004, the stream bed has generally incised (Figure 2.13). Three of the four cross-sections show drops, with only the cross-section at the bridge (310 m) showing a small rise of 3 cm. The average drop in mean bed level is 16.9 cm or 3.1 cm/yr. Therefore, the Mangapoi Stream changed in late 2004 from a rapidly aggrading stream to a gradually incising stream. Under normal climatic conditions (excluding major storms) this trend can be expected to continue. In 2004, about half of the eroded area within this catchment occurred under natural forest and reverting scrub (upper catchment), with the remaining area under pasture in the lower reaches.

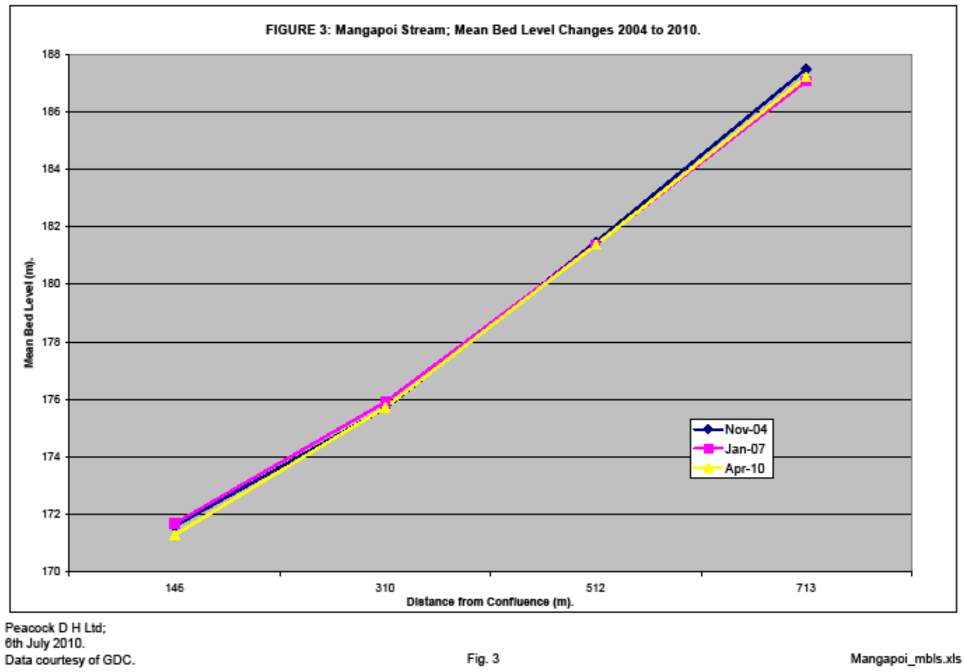


Figure 2.13. Mean bed level changes in the Mangapoi Stream from 2004 to 2010 (reproduced from Peacock, 2010).

Mangawhairiki catchment

The Mangawhairiki Stream is a very short, steeply graded stream next to the Mangapoi stream (see Figure 2.10) that joins the Tapuaeroa River about 2 km downstream of the confluence of the Mangapoi Stream and the Tapuaeroa River. In 2004, 94% of the eroded area of the catchment was in pasture, although significant areas have since reverted to scrub, especially in the steeper, upper part of the catchment. Five cross-sections extending 1.6 km upstream have been surveyed in 1979, 1982, 1984, 1987, 2004, 2007, 2009, and 2010.

The changes in bed levels in the Mangawhairiki Stream are quite different to the changes in the Raparapaririki Stream. While the Raparapaririki Stream was slowly incising during the 1970's, the Mangawhairiki Stream was aggrading rapidly, at a rate of 1,289 mm/yr at the upstream end between 1979 and 1982, mainly the result of the December 1980 storm. The (former) Mangawhairiki bridge was completely destroyed during Cyclone Bola, and large boulders (up to 2 m diameter) were visible in the stream bed following the storm; leading to the conclusion that the bridge may have been struck by a large debris flow. By 2004 there had been minor incision of the stream channel at the bridge (Peacock & Marden, 2004). Since 2004 there has been virtually no change in mean bed level at the most downstream cross-section (154 m) (Figure 2.14) (Peacock, 2010). However, at the bridge site (436 m), there has been an abrupt narrowing of the active channel, evidenced by the appearance of a terrace on the true right bank under the bridge. The active stream bed at this location has dropped about 50 cm (about 8 cm/yr) since 2004. The incision since 2004 has increased in the upstream direction, from 86 cm at 918 m to 2.47 m and 2.98 m at the 1,258 m and 1,606 m locations respectively.

Like the Raparapaririki Stream, this is another example of rapid incision proceeding from upstream to downstream. This is expected to continue provided there are no major storms to reactivate existing gullies or initiate new ones. Being a much shorter and steeper channel, and being well coupled to gully sediment sources, the Mangawhairiki is responding much more quickly to sediment input than either the Mangapoi or Raparapaririki streams.

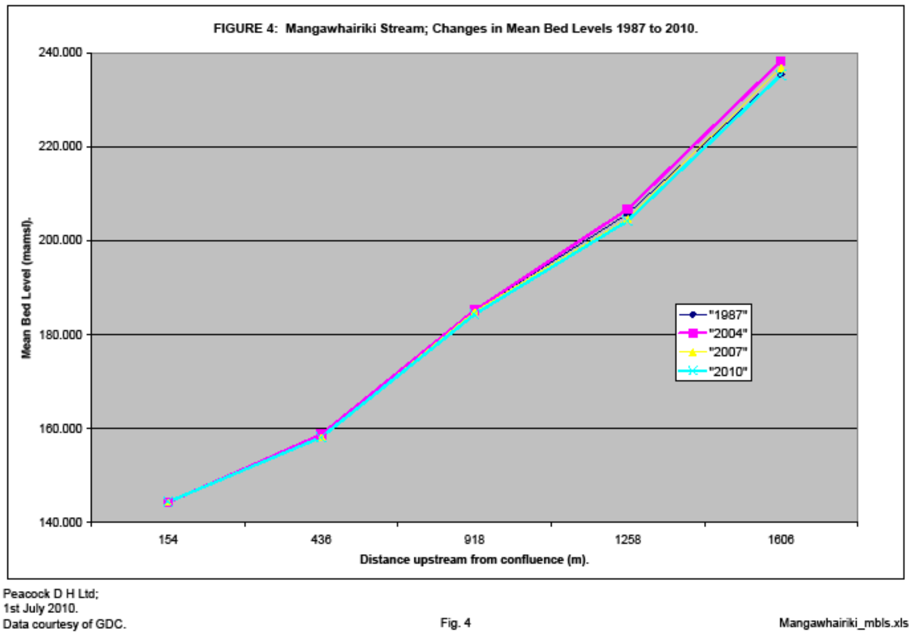


Figure 2.14. Mean bed levels in the Mangawhairiki Stream from 1987 to 2010 (reproduced from Peacock, 2010).

2.9.2.4 Case study 3: Weraamaia catchment

This case study provides an example of decadal changes in sediment supply and transfer in response to deforestation and afforestation in a small catchment.

Changes in sediment flux and stream channel morphology in response to deforestation and afforestation have been identified by Kasai et al. (2005), Kasai (2006), and Parkner et al. (2006) in the 4.8 km^2 Weraamaia catchment (see Figure 2.1). The Weraamaia stream is a tributary of the Mangaoporo River, and its catchment is representative of the gully-prone hill country that supplies much of the sediment to the Waiapu River.

By the early 1920s all but ~0.5 km^2 of the catchment had been deforested. Periodic scrub reversion and clearance followed, until 1971 by which time heavy scrub was established in parts of the catchment. Afforestation began in 1979-1980. Woody vegetation (exotic and natural forest and scrub) has increased from 38% in 1939 to 45% in 1984 to 85% in 1997 (Kasai et al., 2005; Page et al., 2008). By 1939 almost all gullies had been initiated, and several had already stabilised following scrub reversion. Gullies and channels were well coupled, and shallow landslides were also common. Channels were aggrading and widening and bed levels were higher than at any other time during the study period, and between 6.8 and 18.7 m above the 2002 level. Much of this aggradation was due to a high magnitude storm event in 1938 (it was estimated that >700 mm fell in 30 hours). Active gullies decreased from a maximum of 23 in 1957 to 9 by 1988. Channels narrowed and incised in response to the decrease in sediment supply.

Many gullies were reactivated by Cyclone Bola in 1988 (>600 mm fell in 4 days), and shallow landslides were common, even in forested areas. The main source of sediment was a debris flow, derived from a gully complex, which formed a fan (~96,500 m^3) that temporarily blocked the main channel. In response, stream channels again aggraded, especially upstream of the fan. However downstream, the bed level was ~7-8 m below that in 1939. A further reduction in gully activity followed, and by 2003 there were only five gullies active. The majority of sediment in this period was supplied from the debris flow and gullies in areas under pasture. Channels narrowed and incised to their lowest level, further decoupling hillslopes from channels. In the lower reaches of the main channel incision had reached bedrock by around 2008. Total catchment sediment yields with process contributions for four periods and under a forecasted complete forest cover are given in (Table 2.17).

Table 2.17. Changes to sediment flux in the Weraamaia catchment.

Period		**1939-1950**	**1950-1984**	**1988-1991***	**1991-2001**	**Hypothetical forest**
Erosion rate ($m^3 km^{-2} y^{-1}$)	Gullies	6 825	3 456	3 171	1 167	0
	Landslides	18 156	10 569	18 846	723	667
	Channels	20 323	9 469	28 902	4 612	2 252
Catchment sediment yield ($m^3 km^{-2} y^{-1}$)		**45 304**	**23 494**	**50 919**	**6 502**	**2 919**

* Erosion rate does not include debris flow that occurred during Cyclone Bola. After Kasai et al. (2005).

The sediment yield from gullies and gully complexes has reduced since 1939 as the proportion of the catchment in woody vegetation increased. Sediment yield from landslides has followed a similar trend, punctuated by a temporary increase following

Cyclone Bola. Sediment supplied from stored channel sediment has also declined, except for a large influx of sediment from landslides and a large debris flow following Cyclone Bola. As gullies stabilised, channels have incised and the proportion of catchment sediment yield derived from channel beds has increased. For the 1939-1950 period, the proportion of catchment sediment yield derived from channel beds was 45%. This reduced to 40% between 1950 and 1984, and has increased since Cyclone Bola accounting for 57% of total catchment yield (1988-1991), further increasing to 71% for the 1991- 2001 period; approaching the figure of 77% predicted under a hypothetical complete forest cover (Kasai et al., 2005, Kasai, 2006) (Table 2.17). Hillslope erosion and channel incision response to deforestation and to afforestation has been very rapid (20-30 years). Gully development has had phases of expansion and inactivity related to the occurrence of large magnitude storms.

2.9.2.5 Main points

- GDC has monitored river and stream bed levels, through repeated surveys of cross-sections in seventeen selected reaches within the Waiapu catchment.
- Seven rivers have analysed cross-section data with sufficient length of record or number of cross-sections to identify aggradation/incision trends that are related to afforestation.
- These show that some of the river channels in the Waiapu catchment (Tapuaeroa, Mangawhairiki, Mangaraukokore) were incising prior to Cyclone Bola in 1988, whereas most channels (Waiapu, Mangaoporo, Raparapaririki, Mangapoi, Makarika, Weraamaia, Wairongomai) were already rapidly aggrading in response forest clearance and large storm events in 1980 and 1982. Following Cyclone Bola, most of the river channels rapidly aggraded, with extreme rates of aggradation (up to ~2.5 m/yr) measured in the Raparapaririki Stream from 1987 to 2003. In the most recent period captured by cross-section surveys, the larger rivers are still aggrading (Waiapu, Tapuaeroa, Mangaoporo, and Wairongoma). However, incision has started to be recorded in the upper reaches of smaller sub-catchments (Mangaoporo, Raparapaririki, Mangapoi, Mangawhiriki, Makarika, and Weraamaia) and is slowly proceeding to downstream reaches.
- A case study in a small headwater catchment (Weraamaia) has shown that deforestation led to rapid aggradation and widening of stream channels within 30-40 years, and following afforestation, equally rapid incision.
- A case study in a medium-sized catchment (Raparapaririki) has shown that even under steep, naturally forested conditions, once a threshold condition is passed (during a high magnitude rainfall event), severe erosion can occur resulting in very

rapid stream aggradation, and that stream incision can occur within 16 years as hill slope sediment sources are exhausted or revegetated.

- While both channel aggradation – in response to erosion caused by deforestation and by major storms – and channel incision – in response to afforestation – have been rapid (years to decades) in headwater catchments, the likelihood and rate at which incision will proceed downstream is unknown and will depend on the amount and timing of future afforestation.

2.9.3 Future sediment supply

If all gullies that can be stabilised by tree planting or reversion, then future trends of downstream aggradation and sediment yield will be dictated by sediment supply from the number of very large gullies unable to be controlled by afforestation, from sediment stored riverbeds and from other erosion types, especially landslides. Factors determining the amount of sediment entering the Waiapu River in future will depend on the:

- Timing of clear felling of production forest in relation to storm events.
- Management of forest roads and riparian areas.
- Targeting and rate of land use conversion to forest/reversion
- Distribution of new areas of exotic plantation.
- Condition and maintenance of natural forest.
- Maintenance and extent of existing scrub.
- Maintenance of sustainable pastoral systems through effective erosion control plantings.
- Availability of sediment stored in tributary channels.
- Magnitude and frequency of future storm events (expected to increase with the onset of global climate change (IPCC, 2007).

Long-term patterns of sediment supply are likely to be punctuated by sudden large inputs from infrequent, extreme rainstorms and earthquakes (Page et al., 2008). In-channel sediment storage will inevitably be mobilised during future rainfall events. A major determinant of sediment mobilisation will be storms of the magnitude and frequency of the 1938 storm and Cyclone Bola. The cumulative effects of successive storm events and the sediment generated by them are likely to impact large areas of the Waiapu catchment and the marine environment. As afforestation reduces sediment supply from hillslope sources, streams will initiate down-cutting into the sediment stored in upper channel reaches. However, the vast amount of sediment stored in the channel network will ensure that sediment yields and impacts on the lower floodplain will remain high for many decades. Although the rate of hill slope degradation will slow and in some areas show recovery, because sediment yield is regulated by storage within the channel, there will be a time lag between the change in hill slope conditions and any downstream co-benefits (Page et al., 2000). Channels also will continue to be replenished with sediment from landslide scars and gullies for as long as they remain unvegetated (Marden, 2004).

2.9.3.1 Main points

Future trends of downstream sedimentation will be dictated by:

- sediment supply from very large gullies,
- availability of sediment stored in channels,
- targeting and rate of land use change (forestry, scrub and natural forest reversion, and pole planting),
- the magnitude and frequency of storms,
- sudden large inputs from infrequent, extreme rainstorms.

2.9.4 Impacts of sedimentation on freshwater & marine ecosystems

2.9.4.1 Freshwater ecosystems

Freshwater ecosystems are generally adapted to withstand occasional increases in suspended and deposited sediment. However, on-going high-level input of fine sediment has the potential to effect both the invertebrate and fish populations (Ryan, 1991). Increased suspended sediment concentrations can cause a reduction in photosynthesis of plants, increased turbidity, and water temperature increases, causing concomitant changes in the food chain and stream productivity (Ryan, 1991). In most streams, the biological effects of sediment are often caused by deposited sediment rather than suspended sediment *per se*, especially for benthic invertebrates and the deposited eggs of salmonids (Richardson & Jowett, 2002). Deposited fine sediment can be trapped by periphyton, a major food source for invertebrates, and reduce the organic matter content. Deposition of large amounts of fine sediment will fill the interstices between gravel particles, reducing the roughness of the stream bed and causing a reduction in available habitat and spaces for organisms to shelter during high flow, and also causing a reduction in the amount of oxygen available for invertebrates (as well as fish eggs) that live in the top 10 cm or so of the bed material, often smothering them.

Research on the effects of increased sediment concentrations on freshwater ecosystems in the Waiapu River is scarce. Anecdotal accounts summarised by Harmsworth et al. (2002) suggest that the Waiapu River, and its major tributaries, were able to support a healthy population of fish and eel around the turn of the century, and up until about the

1950's. The Waiapu River was considered a major source of kai to Ngāti Porou, and eel (tuna) was a dietary staple. Kokopu and inanga (whitebait) were present up till the 1960's in the Waiapu, Makarika, Tapuaeroa and Mareahara Rivers. In pre-European days, the Raparapaririki Stream (and other tributaries to the Waiapu) supported a population of eels (Harmsworth et al., 2002; Peacock & Marden, 2004), and the literal translation of the name means ―small eels hung out to dry". Prior to Cyclone Bola in 1988, tributaries to the Waiapu (specifically the Tapuaeroa River and Raparapaririki Stream) were typically ‗steep bouldery mountain torrents' (Peacock & Marden, 2004), and in the 1970's and 1980's were known to support a population of trout. Kokopu, inanga and eels are still present in some upper river reaches that are not laden with silt, such as the Maraehara. However, the populations are much reduced, and have disappeared completely from some tributaries (e.g. Tapuaeroa). Brown trout populations are present in the Waitahaia River, where the water quality is suitable.

A NIWA/Landcare Research project examined the freshwater ecology in Weraamaia stream catchment (a tributary of the Mangaoporo River) (Davies-Colley & Halliday, undated). The Weraamaia Stream catchment and its sub-catchments are termed ‗dirty' or turbid streams because of the presence of large amounts of sediment, in particular fine sediment, supplied to and deposited in the active channel. Sediment from gully, earthflow, and landslide erosion is the major pollutant and this has multiple effects on stream ecology. Sediment laden streams such as those of the Waiapu River can also be subjected to other stresses, including shade removal (e.g. loss of riparian vegetation) following deforestation, excess nutrients from runoff, and channel bed and habitat modification. High sediment loads in streams and rivers have important effects on ecological habitats of fish, invertebrates, and birds. Heavy silt deposition in most instances will change the community structure rather than cause a total loss of stream fauna (Ryan, 1991). For example, the fish species present in many of the sediment-choked streams have changed over the years and currently reflect those species more adapted to turbid water and a mobile bedload habitat (e.g. in the Weraamaia Stream, the torrent fish is extremely common).

Research findings indicate that several factors have had a detrimental effect on stream ecology in the Weraamaia stream. These include:

- shallowing of streams leading to less shade and higher water temperatures and greater water velocities,
- the deposition of large amounts of fine sediment, together with the rapid rate of sediment weathering, resulting in the smoothing of channel beds, the infilling of

pools, the degradation of spawning gravel quality, a reduction in bed roughness, and habitat diversity (a pre-requisite for many insects and fish),

- suspended sediment reducing visual clarity and the clogging of the gills in fish.

Ryan (1991) concluded that: (i) the history of land use in the sub-catchment has had a major effect on stream ecology, (ii) water quality and stream health provide an effective integrated method to identify unsustainable land management (nutrient leakage, offsite costs) through key environmental indicators, and (iii) future research on stream restoration must focus on the role and influence of riparian zones on stream health.

The New Zealand Freshwater Fish Database indicates that turbid streams contain fewer native fish than do clear streams largely because high sediment loads have a major effect on native fish habitats (Parkyn et al., 2003). There are two main reasons for lower native fish populations in turbid streams: i) native fish, except for torrent fish, tend to avoid dirty water and ii) turbid waters reduce the ability for fish to feed. This reduction in the ability of fish to feed comes about because turbid water transports and deposits fine gravel, sand, and silt-sized bed material infilling spaces between the larger rocks. Hydraulic roughness is consequently reduced and water velocities increased resulting in a reduction in suitable habitat and less places for fish species to shelter and feed. Coarse substrate and interstitial space are particularly important for native New Zealand species because most are benthic in habit, using the streambed for shelter, foraging, and nesting (McDowall, 2000). The availability of food for fish is also affected by high sediment loads; invertebrate density and taxa richness decline in turbid and unstable streams (Parkyn et al., 2003). Native torrent fish were found in large numbers in the Weraamaia Stream and are probably typical of, and well adapted to, many of the degraded and sediment-infilled streams found in Waiapu catchment.

Streams in soft-rock areas are expected to be somewhat unstable (due to the inherent weakness of the underlying rocks), and those in forested catchments are expected to exhibit better stream health than those in pasture catchments. Parkyn et al., (2003) compared stream health in catchments dominated by pasture, pine plantation, and natural forest land uses in the Waipaoa and Waiapu Rivers. Streams in mature pine plantations in both catchments had generally better water quality (lower faecal contamination and nutrient concentrations) than those in pasture, and tended to approach the condition of reference streams in natural forest (Parkyn et al., 2003, 2006). However, visual clarity and turbidity, and particulate forms of nutrients remained degraded in streams draining pine plantations where deeply incised gullies continued to supply large amounts of fine sediment to streams in the Mangaoporo catchment.

Parkyn et al. (2003) also found that stream stability was the dominant influence on epilithon biomass – a biofilm that converts organic matter into food for larger organisms thereby supporting the food web and removing organic matter from the water – and invertebrate density. Increasing invertebrate taxa richness was related to increasing stream stability. Invertebrate community metrics of stream health were degraded in pasture compared to pine and natural forest, and community composition was influenced by both stability and water temperature. In these streams, establishment of mature pine plantations on pasture in soft rock terrain resulted in an improvement in water quality and stream health conditions to conditions similar to those in natural forest streams (Parkyn et al., 2003). The study also shows that restoration of degraded freshwater habitats in the Waiapu catchment is possible with the application of appropriate catchment management techniques (afforestation and riparian management).

Richardson & Jowett (2002) examined the effects of sediment on fish communities at 38 sites in the East Coast region (27 of which are in the Waiapu catchment), many of which are subject to high sediment loads. The study was carried out in 2000/01, and so does not identify temporal changes that can be related to changing catchment conditions. Furthermore, there can be up to 300% variation in fish densities from year to year at the same site, and from sampling every few months it is apparently hard to get consistent species composition results (I. Jowett pers. comm.). For this reason, and the lack of repeat surveys, no trends are evident in relation to changing catchment conditions, and future monitoring would likely be impractical. They used suspended sediment concentration, median substrate size, substrate stability, and the ratio of the wetted width to the width of the active (non-vegetated) stream channel as indices of sediment load. They showed that high sediment loads in East Coast streams are associated with low native fish abundance and diversity, and poor benthic habitat. The fish communities consisted of nine diadromous (migratory between salt and fresh water) native species, only six of which were classified as abundant. Their data are reproduced in Tables 2.18 and 2.19. They found that site altitude and distance inland were the most important factors in determining the abundance and composition of the fish community.

Table 2.18. Total fish numbers, % occurrence, and the size range of fish caught in East Coast streams. A total of 2,341 m^2 of habitat was electro-fished during the surveys in 2000/01 (reproduced from Richardson & Jowett, 2002).

Species (common name)	Species (scientific name)	Total no.	Occurrence (%)	Size range (mm)
Shortfin eel	Anguilla australis	435	37.8	61–450
Longfin eel	Anguilla dieffenbachii	274	23.8	62–660
Common bully	Gobiomorphus cotidianus	167	14.5	37–111
Redfin bully	Gobiomorphus huttoni	97	8.4	35–96
Inanga	Galaxias maculatus	98	8.5	42–110
Torrentfish	Cheimarrichthys fosteri	65	5.7	65–110
Smelt	Retropinna retropinna	6	1.2	67–111
Bluegill bully	Gobiomorphus hubbsi	-	4	56–67
Koaro	Galaxias brevipinnis	-	4	50–177
Total fish		**1150**	**100**	

Table 2.19. Selected physical characteristics of the sampling sites in the Waiapu catchment (SSC, suspended sediment concentration; D_{50}, median substrate particle size) (reproduced from Richardson & Jowett, 2002).

Site name	Altitude (m)	SSC (gm^{-3})	Turbidity (NTU)	D50 (mm)	Max. depth (m)	Transport index*
Waikaka Stream	15	2.7	2.4	21.3	0.45	0.93
Mangaiwi Stream	45	3.2	4	51.5	0.22	0.44
Mangaiwi Stream	50	3.2	4	20	0.36	0.22
Mangakinonui Stream	55	240	159	19.2	0.15	0.08
Mangamahe Stream	55	3.5	3.4	13.2	0.46	0.2
Mangaoporo River tributary	80	1.4	2.2	12.3	0.17	0.32
Mangaoporo River tributary	130	830	445	13	0.18	0.17
Mangaoporo River tributary	130	660	504	18.5	0.18	0.08
Mangapapa Stream	100	2.6	2.7	39	0.41	0.28
Mangapapa Stream tributary	100	2800	1240	8	0.1	0.07
Mangapoi Stream	170	8.3	9.3	42	0.28	0.03
Mangarara Stream	90	2.9	3.3	22.5	0.28	0.35
Mangareia Stream	60	15	13	11	0.24	0.55
Mangatiti Stream	120	190	142	24.9	0.19	0.32
Mangawhairiki Stream	170	91	75.9	22	0.16	0.03
Mangehu Stream	160	190	138	18.5	0.24	0.05
Maraehara River	50	11	9.2	18	0.46	0.21
Mokokoko Stream	170	2.3	1.8	24.5	0.25	0.69
Paoaruku Stream	40	260	130	14	0.13	0.05
Tukioteao Stream	90	140	106	6.5	0.09	0.18
Waiapu River tributary	30	2.1	3	11.6	0.48	0.36
Waikohu Stream	170	0.8	1.6	90	0.3	0.59
Waikohu Stream tributary	140	2.7	2.3	23	0.35	0.8
Weraamaia Stream	210	1.7	1.3	53	0.25	0.35
Weraamaia Stream tributary	120	1.3	1.7	37	0.13	0.43
Weraamaia Stream tributary	190	1.8	2.1	18	0.22	0.35
Whakatu Stream	60	2.6	3	28.5	0.15	0.62

* Transport index = wetted width/flood channel width (index of channel stability: 1 stable; 0 unstable).

Fish abundance and diversity reduced as sediment load increased among streams, with up to nine fish species in streams with low sediment loads and only two species in streams with high sediment loads. In-stream habitat also varied with sediment load; as load increased, depth and substrate size decreased and velocity increased. However, they conclude that if sediment loads are reduced and habitat improved, diadromous fish communities have a large capacity for recovery. Rowe et al. (2000) in a study of native fish species abundance in turbid rivers of the North Island (including the Waipaoa River), also found that the abundance of adult banded kokopu was reduced in turbid rivers (where suspended sediment concentrations exceeded 120 mg/l for over 20% of the time) and concluded that this was because of reduced recruitment of juveniles in turbid rivers. These results suggest that activities that increase sediment loads in rivers will have a negative impact on native fish communities. However, if sediment loads can be reduced and habitat improved, diadromous fish communities have a large capacity for recovery (Richardson & Jowett, 2002).

2.9.4.2 Marine ecosystems

The suspended sediment yield of the Waiapu River is 20,520 t/km^2/yr (Hicks et al., 2000), which is equivalent to an annual sediment load of 35 million tons of sediment being delivered to the ocean every year (Kniskern et al., 2006a,b). The deposition of this great volume of sediment in the ocean has implications both for sediment transport processes on the continental shelf, and for the organisms that live there. The Waiapu River mouth or estuary is listed in the GDC Proposed Regional Coastal Environmental Plan as having significant conservation value that may be at risk from the high sediment inputs. The physical characteristics of sub-tidal seabed habitats in the East Coast region have been described in general (Foster & Carter, 1997). However, details of the plant and animal communities that live within them are poorly characterised (Gillespie, 2007). This is also the case for the impacts of sediment deposition on these marine environments. High terrigenous sediment inputs have been reported to be a major factor affecting estuarine habitats (Thrush et al., 2004).

Evidence from seismic profiles and core samples taken offshore from the Waiapu River mouth indicate that there has been a change in sedimentation style on the inner shelf within the last century, from well sorted sands to more poorly sorted sands, silts, and clays (Wadman et al., 2006a). Wadman et al. (2006a) suggest that this more recently deposited poorly sorted layer was deposited in response to increased sedimentation rates in the last century, as a result of deforestation in the catchment. Sediment cores revealed that sediments deposited in the Waiapu delta have increased in percent fines (mud: $<63\ \mu$) from an average of 16% over the last 500-700 years, to 97% fines for the last 50-100 year period. Recent research (Wadman et al., 2006b) has also indicated that a significant volume of fine sediment is stored within the inner shelf, rather than being transported further offshore, as previously thought. Sediment transport and redistribution of sediment on the continental shelf is dominated by hyperpycnal deposition (or seafloor-hugging density currents) formed in response to the delivery of large amounts of sediment from the

Waiapu River. Discharge measurements indicate that the Waiapu River reaches hyperpycnal concentrations (>36 kg/m^3) on a yearly basis.

Gillespie (2007) reviewed existing information on the effects of high sediment loads on the marine environment of the East Coast region and recommended that the implementation of an estuary monitoring strategy to document the approximate extent of coastal sedimentation would be an important step towards identifying its effect on marine ecosystems. Gillespie (2007) identified only a handful of studies in the area that included information on benthic communities on the continental shelf (McKnight, 1969), and therefore inferred potential impacts from studies in other parts of New Zealand (e.g. sedimentation effects from the Motueka River on Tasman Bay).

Vast amounts of sediment are delivered to the coast by the Waiapu River, especially during times of flood. Sediment-laden plumes can extend along large areas of the coastline. Very fine-grained sediment can be carried tens of kilometres offshore and transported along the coast by wave action and tidal currents (Gillespie, 2007). Along the relatively exposed East Cape the majority of fine sediments are likely to be flushed away from potentially sensitive near-shore rocky reef habitat and deposited in deeper waters. However, increased near-shore sedimentation rates can still occur resulting in adverse impacts to the reef biota. The species composition and biodiversity can be adversely impacted within these deposition zones and can be severely affected by episodic sedimentation events associated with floods (Gillespie, 2007). During major floods, such as Cyclone Bola in 1988, delivery of large amounts of sediment to the river mouth can result in density currents that extend out over the majority of the continental shelf. These density currents (or hyperpycnal flows) can have catastrophic smothering effects on the benthic communities. Recovery from this scale of event has been estimated to take several years (Battershill, 1993).

Long-term (100-year) sediment accumulation rates (0.2-3.3 cm/yr) derived from sediment cores show that sediments are preserved mainly in the mid-shelf region (at water depths of 60-190 m) (Kniskern et al., 2006a,b). In contrast, short-term accumulation appears to be mostly confined in the near-shore (less than 60 m water depth) environment, suggesting that terrigenous material is temporarily stored in this area. Sediment structure on the shelf is laminated, and bioturbation increases radially away from the river mouth. This pattern of physical (laminations) versus biological mixing (bioturbation), and extremely high sedimentation rates suggest that the fluvial sediment source (i.e. the Waiapu River) is the dominant control on shelf sediment structure, rather than wave energy. The presence of bioturbation in the sediment cores seems to correlate with distance from the Waiapu River mouth, not bathymetry, indicating that the area around the river mouth is too physically disturbed by rapid sediment deposition to allow benthic communities to flourish (Kniskern & Keul, 2004).

Near-shore and (further) offshore habitats are important feeding and/or spawning grounds for a variety of commercially important fish species. Fine sediment deposited on the relatively flat seafloor can be readily re-suspended by tidal and wave generated currents and may interfere with the growth and survival of suspension feeding shellfish (Gillespie, 2007). This is only exacerbated by trawling and dredging.

2.9.5 Main points

- Rivers and streams in the Waiapu catchment are termed ‗dirty' or turbid because of the large amounts of sediment deposited in them from catchment erosion.
- The high rate of sediment supply due to erosion has multiple negative impacts on stream ecology and freshwater habitats.
- In pre-European times, anecdotal accounts suggest eel, inanga, and other native fish species were abundant in the Waiapu River and its tributaries and formed a staple food for Ngāti Porou.
- Some fish species (e.g. torrent fish) have adapted to the high sediment loads and are abundant in the catchment. However, most native fish species now show reduced populations and species diversity has been reduced.
- High sediment loads reduce the quality and quantity of freshwater habitats by causing channel bed and habitat modifications, and suspended sediment can reduce visual clarity, clog fish gills, and degrade spawning gravel quality.
- Fish abundance and diversity decreased with increasing suspended sediment concentrations.
- Establishment of pine plantations in soft-rock hill country catchments resulted in an improvement in water quality and stream health conditions, to conditions similar to those found in natural forest streams. However, when harvesting of forest occurs, water quality and stream health temporarily declines.
- The Waiapu River discharges 35 million tons of sediment to the coast at the river mouth every year.
- The deposition of large amounts of fine sediment impacts on marine organisms.
- Offshore sedimentation rates have increased markedly since the turn of the century, and the sediment is now dominated by mud-sized particles.

- Until the sediment yield is reduced, environmental co-benefits such as improved water quality, a reduction in flood risk, or improved fish habitat will not be realised.

2.10 History of erosion mitigation measures

Phillips & Marden (2004) provided a comprehensive summary of the history of erosion mitigation methods used in the Waiapu catchment. That information is updated and summarised here.

2.10.1 Afforestation trials – Poverty Bay Catchment Board (1948-1968)

Following the widespread erosion during the 1938 storm, it became apparent that erosion damage was far greater on pastoral land than on areas still under natural forest. As a result, in 1948, the Poverty Bay Catchment Board established a large-scale afforestation trial using a range of tree species to mitigate the effects of erosion. The trial demonstrated that once a canopy had formed, runoff was considerably reduced and the advance of eroding gullies was slowed (Rhodes, 2001).

In 1953, the Poverty Bay Catchment Board realized that protection of floodplain areas by stopbanks would not succeed unless land degradation in the catchment was arrested and erosion controlled. At the request of the Catchment Board, the Soil Conservation and Rivers Control Council in 1955 urged Government to purchase eroding farmland to establish dual-purpose exotic forests, for protection against erosion and for production of timber. Planting commenced in 1960 in what was to become known as Mangatu Forest in the headwaters of the adjacent Waipaoa catchment, which ultimately became the nucleus of a much larger forest stretching from Mangatu north to Hicks Bay, including the Waiapu catchment. The conversion of large areas of farmland back to forest did not meet with immediate acceptance. Reluctance to make the change by many in the community, particularly farmers in the worst eroding areas, was understandable because, although the land was in general unstable, where not badly affected by erosion, it was very fertile (Allsop, 1973).

2.10.2 East Coast Project (1968-1987)

In 1963 the Government established a Committee of Inquiry under the Soil Conservation and Rivers Control Act (1941) ‗to inquire into the conservation problems of Poverty Bay – East Cape (an area covering some 600,000 ha) and to make recommendations on a comprehensive control programme'. In 1967, the committee acknowledged that the immense erosion problems were beyond the resources of the farming community and required substantial taxpayer help. In an effort to identify those areas that would need to be retired from pastoral production and that were in most danger of eroding (the ‗critical headwaters‘), the committee introduced a notional ‗Blue Line‘ on the maps accompanying the report. The blue line separated this area from land where the erosion problem was not as great (the ‗pastoral foreland‘). The report prescribed conservation farming for the pastoral foreland and complete afforestation for the critical headwaters area. Money for on-farm soil conservation works (non-blanket forestry) was made available via Government subsidy through soil conservation programmes.

The New Zealand Government responded by approving a programme for the New Zealand Forest Service (NZFS) to purchase and plant the unforested parts of the critical headwaters to control erosion and enhance productivity. Secondary objectives of the scheme were to maintain the productivity of the land, promote economic and social development and establish production forests (Rhodes, 2001). This became known as the East Coast Project. Planting of exotic forest for erosion control began in 1969 in the headwaters of the Tapuaeroa catchment, the most highly eroded sub-catchment of the Waiapu River (Harmsworth, 1997). By 1985 about 40,000 ha of exotic forest had been planted on the East Coast (Marden et al., 2011).

The segregation of the headwaters from the pastoral foreland was not well supported by the local farming community, and early forest planting was slow (Rhodes, 2001). By the mid-1970‘s it was apparent that this division of land was no longer appropriate and four categories of land were proposed based on LUC units for land uses according to the land‘s physical characteristics and susceptibility to erosion. The four categories proposed by a joint working group in what became known as ‗The Red Report‘ were seen as a better approach to formulating erosion priorities than the two categories of the Taylor Report. However, the NZFS continued its planting programme according to the Blue Line concept.

A total of 36,100 ha of land on the East Coast, of which 25,800 ha was severely eroded or erodible, was acquired and planted by the NZFS as part of the East Coast Project. In addition, the NZFS established a further 1,809 ha of protection/production forest on farmland by way of forest encouragement grants. However, 110,000 ha of highly erodible land remained unplanted. The planting programme ended in 1987, when the NZFS was corporatized. The new Forest Corporation was commercially focused and the highly erodible land was not seen as economically viable for forestry (Rhodes, 2001).

2.10.3 East Coast Project Conservation Forestry Scheme (1988-1993)

In 1988, following the devastating effects of Cyclone Bola, the Government agreed to provide $8 M to directly subsidize a new East Coast Project Conservation Forestry Scheme. The funding was to be spread over 5 years (1989–93), and was aimed at establishing about 3,000 ha of protection forest per year. The Government also agreed that the funding would be provided as a subsidy covering two-thirds of the cost of establishment and that the remaining one-third should be met by the region through the East Cape Catchment Board. Oriented purely towards protection forestry, subsidies did not cover ongoing pruning or thinning costs. The East Coast Project Conservation Forestry Scheme was administered by GDC, but excluded the Waiapu catchment. This scheme was phased out in 1993 following the establishment of the East Coast Forestry Project (ECFP) in 1992 (MAF, 2005), but by that time it had established 13,578 ha of forest over the 5 years.

2.10.4 East Coast Forestry Project (1992-present)

The East Coast Forestry Project (ECFP) was introduced by the Government to address the Gisborne District's erosion problem, provide employment and regional development, and to recognise environmental needs on individual properties (MAF, 2001). Erosion had become more serious, and permanent land management changes on a large scale were recognised as being necessary. In particular, the area from Tolaga Bay to Te Araroa had received little attention and the erosion problems had worsened (Rhodes, 2001). The objective of the ECFP was to achieve sustainable land management by promoting commercial forestry to control present and potential erosion of severely eroding land in the Gisborne District by 2020. Erosion control on 'target' land will be achieved by changing current land use in any cost-effective way, including planting with radiata pine or other species, gully planting and actively managing the reversion of pastoral land to indigenous scrub/forest. The ECFP provides grants to landholders to enable them to carry out these kinds of activities on sites identified as 'target land', together with any non-target land directly associated with target land (MAF, 2001). The original goal of the ECFP was to facilitate planting of 200,000 ha of moderately to severely eroding land over 28 years. The objectives of the ECFP align with the aims of the Combined Regional Land and District Plan of the GDC, under the Resource Management Act (1991). The GDC is therefore closely involved in the management of the project (Rhodes, 2001).

Under the ECFP, the minimum grant area eligible for tender is 5 ha for all erosion control treatments. ‗Target land' is defined as Category 3b, 3c, and some category 4 land as used in the earlier Red Report. This land is vulnerable to erosion by gullying, slumping, or earthflows. More specifically, ‗target land' consists of the following Land Use Capability units 7e18, 19, 21, 22, 23, 24, 25; and 8e 2, 3, 4, 5, 6, 7, 8, 9. These LUC units are described in Jessen et al. (1999). The ECFP target land is further defined as land that does not have either vegetation cover providing effective erosion control, or vegetation cover capable of doing so in the near future. Target land is generally bare or in pasture, and may include areas of scattered or stunted scrub.

Amendments and modifications to the project have occurred since its inception as a result of various reviews and these have been included in updated guidelines (MAF 2000, 2001, 2002, 2011). These include changes to the nature and description of target land, the range of species that could be planted, the clearance (or not) of indigenous scrub (manuka (Leptospermum scoparium) and kanuka (Kunzea ericoides), inclusion of farm gully planting, and the objective of nature conservation on individual properties was added (Bayfield & Meister, 1998). In 2011 the Afforestation Schemes review panel (MAF, 2011b) considered adding clearing of land with existing manuka and kanuka but this was rejected on the grounds that manuka and kanuka already provides protection from erosion (as per Bergin et al., 1993).

Bayfield & Meister (1998) concluded that if the ECFP was to continue either for the full-intended term or as a strategic wind down, some modifications needed to be made. They recommended that a new goal and objective be adopted for clarity of purpose. In redefining the goal they concentrated on the major purpose for Government intervention — soil erosion control. They acknowledged that although this primary focus denied the importance of employment, regional development, nature conservation, and Māori development, these would follow from achieving the overriding goal. They suggested a revised goal:

> ”To achieve sustainable land management on 60,000 hectares in the East Coast Region on severely erodible land by changing land use.―(Bayfield & Meister, 1998, executive summary).

They recognized that commercial forestry was only one of the instruments that could be used to achieve the objective, but considered it was likely to be the main one. In 1999, Cabinet agreed to modify the primary goal of the ECFP to reflect Bayfield & Meister's (1998) recommendation.

Since the 1998 ECFP review, other treatment options for controlling erosion on farmland have become eligible for funding through the ECFP. These include the use of poplar and willow poles and/or wands. Poplars and willows are an option for controlling/preventing erosion where soils, soil moisture, and erosion (type and severity) are conducive to establishment (O‘Loughlin et al., 2008). Alternative treatments, such as wide space poplar/willow planting have increased in popularity since it allows continued grazing. However, Bayfield & Meister (2006) reported conflicts between GDC and ECFP regarding planting densities and patterns. This was addressed by a MAF/GDC organised workshop in 2008 to develop guidelines for the treatment of eroding areas where poplar/willow pole planting could result in successful erosion control outcomes (O‘Loughlin et al., 2008). Reversion to indigenous vegetation cover has recently become more popular. It is often the only option for landowners with severely eroding land where afforestation or pole planting does not represent an effective option and imposes no erosion risk around clear-fell harvesting. Bayfield & Meister (2006) concluded that because of the uncertainty around the Kyoto Protocol after 2012, landowners are likely to be hesitant to participate in this mechanism, especially given the current high returns to pastoral farming.

2.10.5 GDC Land Overlay 3A

Recently GDC introduced a Resource Management Act land use rule requiring tree establishment on the same target LUC units as used in the ECFP, but mapped at a more definitive detailed scale to allow for enforcement. The rule is used to identify ‗the worst of the worst‘ eroding land in the Gisborne District, and requires effective tree cover on Land Overlay 3A (LO3A) land for erosion control. The scheme, now referred to as Land Overlay 3A (previously known as Land Overlay 4), generally delineates a buffer area around actively eroding gullies, leaving large parts of the associated sub-catchments unforested. LO3A target land is identified on the basis of NZLRI LUC units, and consists of the following LUC units: 7e18, 19, 21, 22, 23, 24, 25 and 8e2, 3, 4, 5, 6, 7, 8 and 9 which do not have sufficient vegetation cover to provide effective erosion control or vegetation cover capable of doing so in the near future (MAF, 2000; Crippen, 2006). The LO3A rules rely on cost effective treatment options being available under the ECFP. In practice, the ECFP supports the implementation of GDC LO3A rules, which specify effective tree cover by 2021 (MAF, 2011b). Effective tree cover can be achieved through exotic or indigenous afforestation or pole planting.

LO3A land differs from ECFP target land in that it is mapped at a more detailed scale and does not include planting of non-target land directly associated with target land (MAF, 2001). Due to differences in the scale of mapping, ECFP target land includes a greater area of land, incorporates more gullies, and involves planting of a greater portion of the catchment surrounding each gully (Herzig et al., 2011). However, to achieve ‗effective tree cover', land surrounding the identified LO3A area would also need to be treated and both schemes can include planting of non-target land directly associated with target land. Effective stabilised tree cover is required to be established on LO3A land areas. This may necessitate additional tree establishment within the catchment in order to do so. Tree establishment boundaries are not limited by LO3A boundaries. Land parcels in LO3A are identified by their status, which indicates whether the land is bare rock, open ground (or pasture), partially planted (soil conservation planting or forestry), scrub reversion/native bush, or fully planted in trees (including forestry and soil conservation planting) (Crippen, 2006).

2.10.6 Permanent Forest Sink Initiative *(*PFSI)

The PFSI is a government initiative that promotes the establishment of new, permanent forests on previously unforested land, from which landowners can obtain tradable Kyoto Protocol compliant emission units in proportion to the carbon sequestered in their forests (MAF, 2007). Forest area must be a minimum of 1 ha, with greater than 30% of tree cover expected to reach a height of 5 m at maturity. To be eligible, the land must not have been forest on 31 December, 1989, and a change in land management practices must have occurred to promote forest growth. Under the PFSI, forest includes exotic forestry, reversion of pasture to natural forest, kanuka and manuka scrub, and soil conservation plantings, as long as they meet the other requirements of the PFSI.

2.10.7 Afforestation Grant Scheme (AGS)

The AGS is another government initiative first flagged in the Sustainable Land Management and Climate Change: Options for a Plan of Action discussion document released in December 2006 (MAF, 2006). Under the AGS, landowners can receive a government grant for planting new forests on Kyoto-compliant land (that is, land that was not forested as at 31 December 1989). Grant recipients will own the new forests and earn income from the timber, while the Crown will retain the carbon credits generated under the Kyoto Protocol, and take responsibility for meeting all Kyoto harvesting and deforestation liabilities. Another objective of the AGS is to establish new Kyoto-compliant forest in areas where it will help reduce the likely impacts of climate change and generate other environmental benefits, for example, where it will reduce erosion, nutrient leaching, and flood peaks.

The goal of the Afforestation Grant Scheme is to encourage the establishment of new forest land in New Zealand in order to stabilize the greenhouse gas concentration of the atmosphere (by converting carbon dioxide from the atmosphere into carbon stored in wood). Priority will be given to afforestation proposals that will also reduce the risk of soil erosion, improve water quality, and improve biodiversity (http://www.maf.govt.nz/climatechange/forestry/initiatives/ags/page-01.htm).

While the AGS is targeted specifically at the planting of exotic forests, the PFSI provides opportunities for landowners to afforest or retire marginal land and still receive an income. Land that is allowed to regenerate into scrub (gorse and broom or manuka and kanuka) or natural forest, as well as land that has erosion control plantings, is eligible for compensation under the PFSI. These two initiatives may provide incentives for landowners in the Waiapu catchment to treat eroding and unproductive land through permanent afforestation, erosion control planting, or indigenous reversion. It should be noted that ECFP target land is not eligible the AGS unless it is less than 5 ha in area. The AGS might be useful to complement ECFP planting, and tackle adjacent areas.

2.10.8 The Emissions Trading Scheme (ETS) (Forestry) (2008- present)

The Emissions Trading Scheme (ETS) (Forestry) is the main policy instrument of the Government to encourage afforestation and reduce deforestation (MAF, 2011a) to reduce net greenhouse gas emissions as part of New Zealand's international obligations, under the Kyoto Protocol (http://www.maf.govt.nz/environment-natural-resources/emissions-trading-scheme.aspx). MAF administers the scheme for the forestry and agriculture sectors, in conjunction with the Ministry for the Environment and Ministry of Economic Development. Forestry entered the scheme in 2008, and agriculture is set to fully enter the scheme in 2015, with voluntary reporting starting this year. The ETS is a price-based mechanism.

The ETS classifies forests differently depending on whether they were first established after 1989 (Post-1989 forest land) or before 1990 (Pre-1990 forest land), largely mirroring the rules under the Kyoto Protocol. Under the ETS, forest land is defined as being at least 1 ha with forest species that has, or is likely to have tree crown cover of more than 30% on each hectare. Forest land does not include land that has, or is likely to have tree crown cover with an average width of less than 30 m. Forest species are defined as trees capable of reaching five metres in height at maturity, excluding tree species grown primarily for the production of fruit and nut crops.

2.10.9 Ngāti Porou SMF project

In 2008, He Oranga mo nga Uri Tuku Iho Trust, on behalf of Ngāti Porou, secured an MfE Sustainable Management Fund (SMF) grant of $100,000 for a community based rehabilitation and enhancement project. The project is entitled ‗Waiapu Koka Huhua – Waiapu Mother of Many', and the key focus of the project is on sustainable land use, water, and communities (Warmenhoven, 2008). The project goal was to establish restoration initiatives in the Waiapu catchment. The funding was to be used by Ngāti Porou Hapu to develop a restoration framework and strategy to identify key people and locations in the catchment for the restoration project.

The project aimed to involve key stakeholders in undertaking practical, effective restoration initiatives to improve sustainable land and water management in the catchment. The project was to be guided by key findings developed by the locally led research project Māori Community Goals for Enhancing Ecosystem Health (TWWX01) conducted in 1998-2003 (Harmsworth et al., 2002). At least five restoration initiatives (across all five sub-catchments of the Waiapu River) to be implemented addressing significant areas/issues (within each sub-catchment) were planned. A local nursery facility, community education, stakeholder relationships, and resources was to be established/facilitated by the Trust to support these objectives. Afforestation, regeneration, riparian zone management, stock and pest management and maintenance/protection of forested areas were key approaches that were to be used to meet project outcomes and objectives.

The project ran for one year before funding was stopped. During that year, the focus of the project was on community education, engagement with landowners and the GDC, and establishment of a small native plant nursery (which is now in recess). More specifically, the following activities were undertaken (T. Warmenhoven, pers. comm.):

- Riparian planting on GDC land (a rest area) near Ruatoria.
- Planting at Reporua for coastal erosion.
- Work with farmer at Ihungia on fencing and pest and weed management.
- Work with two farmers in the Tapuaeroa area on manuka reversion.
- A strategic plan for Mangawhairiki Blocks was developed.
- Collaboration with Tairawhiti Polytechnic on a horticultural programme in Ruatoria (still operative).
- Seed collection and propagation with local schools.

2.10.10 Main points

- Following the 1938 storm, it was apparent that erosion was far greater on pastoral land than on areas still under natural forest, and in 1948, the Poverty Bay Catchment Board (PBCB) began large scale afforestation trials using a variety of tree species to mitigate erosion.
- PBCB realised the link between erosion in the headwaters and protection of the floodplain downstream.
- Planting began in the headwaters of the Waipaoa River in 1960 (Mangatu Forest) and in the headwaters of the Waiapu River in 1969. Forests were to be dual purpose; for protection against erosion and production forests.
- There were various planting schemes developed by the Governments of the day to encourage planting of the ‗critical headwaters' of the major river systems on the East Coast. Government initially purchased land for planting, then provided subsidies to establish protection forestry.
- The ECFP was introduced in 1992 to achieve sustainable land management by promoting commercial forestry to control present and potential erosion on 200,000 ha of eroding land. This land area was revised to 60,000 ha in 1998. Target land was defined by MAF, based on NZLRI LUC units.
- The ECFP objectives align with GDC's Combined Regional Land and District Plan under the RMA, so GDC is closely involved in the management of the project. However, the GDC defined its own target land (LO3A), based on mapping at a much more detailed (property) scale to allow for enforcement and enable the implementation of farm plans.
- By 2011, 35,552 ha have been planted, 66% of which was target land. Included in this area were 1,196 ha of pole-planting and 3,437 ha of reversion to scrub. A total of 96% of treatments were afforestation with Pinus radiata.
- Other Government incentives for afforestation include the PFSI, the AGS, and the ETS (Forestry).
- A Ngāti Porou project to implement restoration initiatives in the catchment was funded by an MfE SMF grant. However, the project was funded for only one year.

2.11 Effectiveness of past & current erosion mitigation measures

2.11.1 Effectiveness of current policies to improve erosion control

To date, there have been about 54,000 ha of afforestation in the Waiapu catchment. In 2011, the total amount of land planted in the Waiapu catchment under the ECFP was 28,459 ha, of which 46% was target land (R. Hambling, pers. comm.). The area of target land remaining in the Waiapu catchment is estimated to be 13,526 ha (data supplied by MAF – Gisborne office)[1]. The current rate of treatment falls short of achieving the target of treating all remaining target land by 2020. Across the East Coast, over 96% of afforestation in the period from 1993-2005 was using *Pinus radiata* (Meister, 2006). MAF (2011) reported increased interest in the scheme in 2010, supposedly driven by the opportunity for carbon credits under the ETS (Forestry) in combination with the ECFP and the introduction of GDC LO3A rules. A summary of the recently planted and approved ECFP forest in the Waiapu catchment is provided in Table 20. The increase in planting in 2011 is 250% greater than the two previous years due to the GDC LO3A rule coming into effect in 2011. The combined effect of the introduction of LO3A, and carbon investment opportunities lifted ECFP achievement in 2011 in the Gisborne District by 300%.

Table 2.20. Recently planted and approved ECFP forest in the Waiapu catchment.

Status	Year	Area (ha)
Planted	2009	703
	2010	723
	2011	1,795
Approved	2012	655
	2013*	765
	2014*	446

* Areas are interim only and are subject to further annual application rounds 2012 and 2013.

[1] Note that MAF have indicated that there is uncertainty around their estimate of ECFP target land not yet treated. MAF suggest that the estimated figure of 13,526 ha may be on the high side.

2.11.2 Effectiveness of erosion mitigation methods

A well maintained, continuous, dense ground cover provided by improved pasture is sufficient to reduce surface erosion (sheetwash) in most hill country areas. However, the most effective vegetation for controlling various types of mass movement and fluvial erosion, especially on highly erodible land, is mature/closed canopy natural or exotic forest (Basher et al., 2008). Several researchers (Phillips et al., 1990, Marden & Rowan, 1994, Bergin et al., 1995, Dymond et al., 2008) have shown that the incidence of shallow landslides on steep slopes covered in closed-canopy forest is often at least 90% less than on slopes in pasture. Basher et al. (2008) compiled and summarised available data from research on the effectiveness of various vegetative methods for controlling different types of erosion. These data are presented in Table 2.21.

Table 2.21. Effectiveness of vegetative methods for controlling different types of erosion (Reproduced from Basher et al., 2008).

Erosion type	Method	Reduction in erosion (%)
Surface	Continuous, dense, improved pastures	50-80[1]
Landslide	Forest (mature)	Mostly >90[2]
	Spaced planted trees (<12 m spacing), well maintained	50-80[2]
	Partial tree planting and/or poorly maintained older plantings	10-20[2]
Gully <2 m deep	Trees spaced 2-4m	90[3]
	Trees spaced 4-8m	35[3]
Earthflow	Trees spaced 3-5m	100[3]
	Trees spaced 8-10m	35[3]

[1] Compared to unimproved pasture.

[2] Compared to areas of slipped ground.

[3] Percentage of sites where treatment effective.

The effectiveness of different erosion mitigation methods used in the Waiapu catchment are summarised below.

2.11.2.1 Afforestation

In a study of the effectiveness of afforestation in controlling gully development and stabilising gullies in Cretaceous rocks in the adjacent Waipaoa catchment, Marden et al. (2005, 2011) found the key determinants are the size and shape of gullies at time of planting. The probabilities of stabilising the gullies were: >80% for gullies <1 ha in area, ~60% for gullies 1–5 ha in area, 50% for gullies of 5 ha, and little chance of success for gullies >10 ha in area. Linear gullies are more likely to be stabilised than amphitheatre-shaped gullies.

Marden et al. (2008, 2011) determined that the probability of gully stabilisation by afforestation was linearly related to gully area (size) and the number of years since planting. For the majority of gully sizes, afforestation effectively closes them down within 20 years of planting (Marden et al., 2005). However, the time required for stabilisation increases with increasing gully area (Marden et al., 2011). Approximately 90% of gullies ~1 ha and less in area had stabilised within 20 years of planting, 60% of gullies of 5 ha in area had stabilised after 20 years, and by 30 years 90% of 5 ha gullies had stabilised (Marden et al., 2011). For gullies >10 ha, the model predicts that between 20% and 36% of gullies will stabilise within 20 years, and after 30 years 51-71% of gullies will stabilise. None of the planted gullies that were greater than 20 ha in size at the time of planting had stabilised within 30 years of planting (Marden et al. 2011). The results of the gully stabilisation model runs are shown in Figure 2.15.

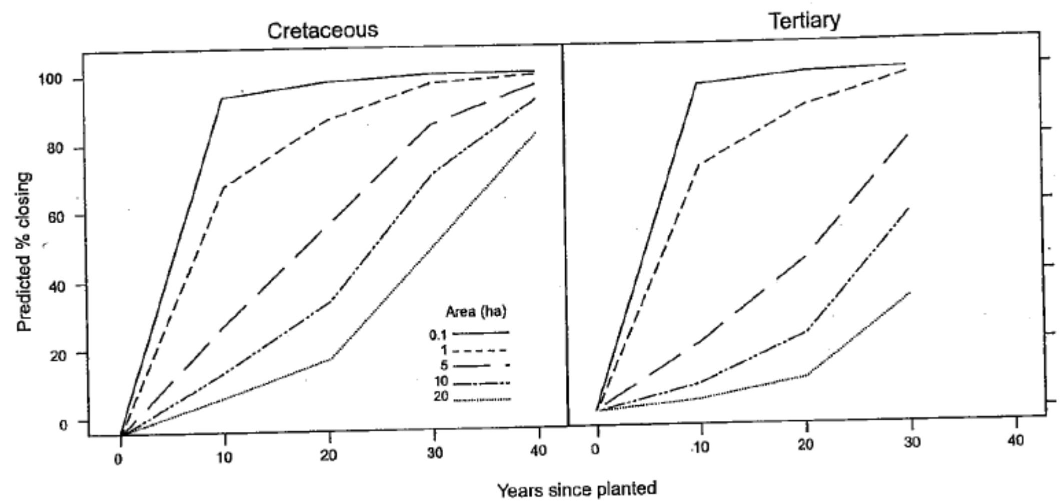


Figure 2.15. Predicted probabilities of a gully stabilising in response to afforestation plotted against years since planting for 0.1 ha, 1 ha, 5 ha, 10 ha and 20 ha-sized gullies within Cretaceous and Tertiary terrains (reproduced from Marden et al., 2011).

Analysis of the 1,468 gullies present in the Waiapu catchment in 1957 and of those subsequently planted in exotic forest, a 28% reduction in total gully area was achieved. A 64% reduction in gully area was achieved within one forest rotation (~27 years) in the Waipaoa River, where Cretaceous rock types occupy only 8% of the catchment area (Marden et al., 2005). The reduction in gully area over time was attributed to the effects of canopy closure, which occurs within 8-10 years after planting (Marden & Rowan, 1994). A mature closed canopy stand of *Pinus radiata* has the potential to reduce runoff by 25-30%, influencing the hydrology and erosion activity within the gully (Pearce et al., 1987). For all but the largest and most active gullies, afforestation is most effective when the entire drainage basin surrounding the gully is also planted (Marden et al., 2005).

Lithology has little influence on gully stabilisation for small gullies (<5 ha). However, Marden et al. (2011) found that larger gullies on Tertiary terrain are less likely (by almost 50%) to be stabilised by afforestation than similar sized gullies on Cretaceous terrain. This difference was attributed to the occurrence of mass movement erosion reducing the slope of gully walls in Cretaceous terrain and providing more favourable planting areas on which plants can be established.

Herzig et al. (2011) recently developed a numerical ‗gully-complex model' to assess the effectiveness of past and future afforestation schemes for the Waiapu catchment, along with the neighbouring Waipaoa and Uawa catchments. The model used a gully database developed by interpretation of 1957 and 1997 aerial photography of the region. The gully database was further augmented by forest stand information on the date of forest planting. Herzig et al. (2011) combined empirical functions of gully initiation, incision, spatial extension, stabilisation (closure), the impact of forest cover, and the influence of the underlying geology developed by numerous researchers over the last two decades (DeRose et al., 1998; Betts & DeRose 1999; Betts et al., 2003, Marden et al., 2005, 2008, 2011), to model gully development in space and time. The model simulates the growth and shut-down of gullies based on the input database, on an annual time step. The annual sediment yield for each gully was estimated, and summed for whole catchments using several different afforestation scheme scenarios. The different scenarios explored the influence of gully size on effectiveness, tested the effect of afforestation schemes to-date using actual planting data from 1957 to 2008, and future planting schemes based on ECFP target land and GDC's LO3A. These scenarios are for total afforestation of ECFP target land and LO3A at various dates i.e. results are for the whole Waiapu catchment. Assessments of the impact that other scenarios would have on gully stabilisation and sediment yield (involving lesser amounts of afforestation and their spatial distributions), have yet to be made.

Herzig et al. (2011) and Marden et al. (2011) found that afforestation schemes have been effective at reducing the sediment yield derived from gullies in the Waiapu catchment by approximately 17% from what it would have been without afforestation. Reductions in sediment yield of 33% and 20% were estimated for the Waipaoa and Uawa catchments respectively. The differences in sediment yield reduction between the catchments were attributed to differences in the timing and amount of land planted in each catchment, with a greater proportion of gullies being planted at an earlier date in the Waipaoa Catchment. Although afforestation has been successful in reducing the sediment yield from gullies (c.f.

no afforestation), the area of gullies by 1997 had actually increased by approximately 48% (incorrectly reported as 33% in Marden et al., 2008) since pre-afforestation (the 1960's) due to the growth of existing gullies, and development of new gullies in gully-prone areas of land that have not been treated (afforested) (Marden et al., 2008). Based on an update of the gully area at 2008 (provided by Landcare Research for this study) the increase in gully area between 1957 and 2008 has only been 17%. This is due to a decrease in gully area since 1997 (Table 4.12). By 1997, 80% of the gullies in the Waiapu catchment had not been planted, and an additional 850 new gullies were initiated (Marden et al., 2008). Despite a reduction in sediment yield of 17% due to afforestation (from what it would have been without afforestation) in the Waiapu catchment, forested gullies continue to contribute sediment to the river system. Marden et al. (2011) estimated that forested gullies contribute 23% of the total gully derived sediment.

Herzig et al. (2011) and Marden et al. (2005, 2011) concluded that the most successful afforestation strategy in this highly erodible landscape is to reforest whole sub-catchments in which gully erosion occurs. If all gullies had been forested by 2010, the sediment yield derived from gullies could have been reduced by half (from 22 Mt/yr to 11 Mt/yr) by 2050. It should be noted that Marden et al. (2008) calculated that sediment production from gullies was 17 Mt/yr for the period 1957-1997. The larger 22 Mt/yr calculated by Herzig et al. (2011) is due to the increase in gully area by 2010. However, if afforestation efforts were terminated today, and new gullies were also left untreated, the sediment yield from gullies would double (to 44 Mt/yr) for the same period. They note that this value is approximately one third of the sediment yield derived from all North Island Rivers combined.

A comparison was also made of the effectiveness of planting ECFP target land with GDC's LO3A (Herzig et al 2011). ECFP target land is defined in Section 2.10.4, based on LUC units, and includes any planting of non-target land directly associated with target land (MAF, 2001). The model (Herzig et al 2011) shows that afforestation of ECFP target land is more effective in reducing sediment yield derived from gullies compared to GDC's LO3A, because ECFP target land incorporates more gullies and involves planting of a greater portion of the catchment surrounding each gully. Planting a larger area surrounding gullies increases infiltration, reduces the amount of runoff reaching gullies, and increases stability around gullies. Other significant findings of Herzig et al. (2011) is that the earlier the planting is completed the greater the reduction in annual sediment yield will be, and to achieve a significant and permanent reduction in sediment yield, all remaining gullies, plus newly initiating gullies, must be afforested. However, even for this scenario, the model does not predict a complete shut-down of sediment supply because sediment production from large gullies (>20 ha in size) is unlikely to decline significantly (Marden et al. 2011). The modelling shows that the most effective afforestation scenario is to plant all ECFP target land by 2020. This will result in a catchment sediment yield from gullies of 1,069 Mt for the 2008-2050 modelling period or 30.6 Mt/yr (A. Herzig, pers. comm.), compared with 45 Mt/yr if no further planting was to take place. Physical evidence that afforestation has been effective in stabilising gullies and reducing sediment production rates includes channel narrowing and incision (Kasai et al., 2005; Peacock & Marden, 2004; Peacock, 2011), the survival of forest plantings to increasingly form a closed canopy on previously active gullies, channel incision into depositional fans associated with gullies, and the stabilisation of these fans. Although there has a been a decline in sediment yield from forested gullies over the last 40 years (17%), sediment generation from gullies at the catchment scale remains high, because large untreatable gullies and newly formed gullies are significant sediment sources (Marden et al., 2011).

Marden et al. (2011) estimate that any appreciable reduction in gully derived sediment yield will take at least 40 years. Until a significant reduction in sediment production from gullies is achieved, other potential environmental benefits such as improved water clarity and quality (Parkyn et al., 2006), a reduction in channel aggradation and flood risk (Gomez et al., 2003), and the cost savings associated with bridge replacement, bank protection works, and repairs to flood damaged roads will not be realised (Marden et al., 2011; Herzig et al., 2011).

Afforestation is also successful in reducing sediment yields derived from shallow landslides. Reid & Page (2002) showed how knowledge of land type and storm magnitude/frequency distributions can enable better targeting of afforestation. They modelled how different patterns of afforestation might affect sediment delivery by landslides in the Waipaoa catchment, by a random series of rainstorms over 100 years. They calculated that the 7% of landslide-prone land converted from pastoral farming to production forestry between 1990 and 1995, produced a 10% decrease in landslide sediment delivery. However, had the planting targeted the most landslide-prone land it would produce a 30% reduction in landslide sediment delivery. Furthermore, a 50% reduction could be achieved by targeted afforestation of 12% of landslide-prone land, but the amount of forestry required would increase to 30% if non-targeted (Figure 2.16). While such an analysis has not been carried out in the Waiapu catchment, it can be expected that targeting afforestation on landslide-prone land would produce similar results.

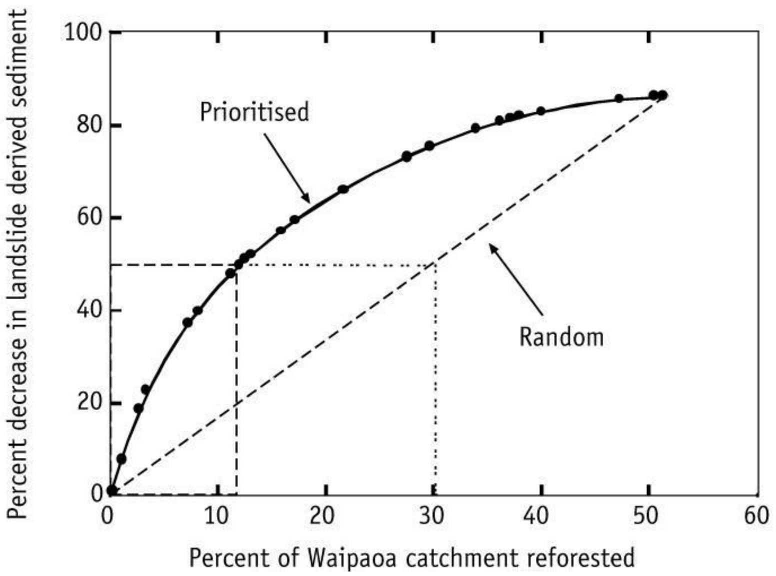


Figure 2.16. Percentage change in landslide-derived sediment for different levels of afforestation under two strategies for prioritising afforestation sites in the Waipaoa catchment (reproduced from Reid & Page, 2002).

Research on the impacts of afforestation in the Waipaoa catchment, where the highly eroding headwaters area was planted in pines by the Forest Service between 1959 and 1982, showed that sediment yield from gully erosion averaged 2,480 t/ha/yr before afforestation, and then declined to 1,550 t/ha/yr (DeRose et al., 1998). Other important points learnt from the Waipaoa River research about afforestation relevant to the Waiapu River include:

- Where terrain is highly erodible due to geological instability, suspended sediment yields remain initially high after afforestation.
- The high sediment yields persist for several decades due to a ‗lag effect', until sediment stored in and near the channels is transported downstream.
- Sediment yields gradually decline, relative to those from rivers in equivalent terrain still used for farming.

2.11.2.2 Space-planted poplars & willows

Factors determining the effectiveness of space-planting for erosion control include; planting density, tree spacing, tree root length density, tree root mass density, location of trees in relation to slope, topography and water movement, age and maintenance of trees (McIvor et al., 2011).

In an early investigation of the performance of biological erosion control measures applied to support pastoral land use in soft rock hill country, Thompson & Luckman (1993) found that vegetation-based treatments, centred particularly on use of fast-growing poplars and willows, successfully controlled a range of gully erosion and earthflow mass movement problems on Tertiary mudstone and Cretaceous argillite rock types in the East Coast region. Treatments using space planted poplars and willows on the gully channel and wall were found to be successful at 63% of earthflow sites, and 42% of gully erosion sites. However, less than satisfactory results were achieved when the gullies were deep (2-5 m), very deep (>5 m) or located on bentonite or argillaceous lithologies (Thompson & Luckman, 1993).

In a study of erosion caused by the 2004 Manawatu storm, Hicks & Crippen (2004) showed that the presence of scattered willows and poplars reduced landslide erosion in upper slope areas by 34% compared with open pastures. Post-storm damage assessments of poplar and willow plantings showed that, where implemented appropriately, poplar and willow plantings substantially reduced landsliding in hill country grazing lands, by between 50–80%, even during exceptional storms such as Cyclone Bola in 1988 (Hicks, 1992). They also showed that damage reduction was minimal on hill slopes where plantings were absent, inadequate or not maintained (Hicks, 1992).

A comprehensive study by Douglas et al. (2011) covering 53 sites with poplar trees, six sites with willow trees and six sites with eucalypt trees recently exposed to a severe storm event, showed that over all sites, trees reduced the extent of landsliding by an average of 95% compared with landsliding on nearby pasture control sites. The treed sites contained between 4-10 trees, and at densities between 32-65 sph. Landsliding occurred at 10 of the 65 sites, and the greatest extent of landsliding occurred where trees were <30 cm diameter at breast height (DBH). They concluded that spaced trees dramatically reduced the incidence and severity of landsliding on erodible slopes, and that they were even more effective when average DBH was 30 cm or greater. Mature plantings of 30-60 sph (13-18 m spacing) were very effective in controlling landsliding.

There have been differing opinions about the effectiveness of various regimes of space-planted poplars and willows, which has led to doubt and confusion among some landowners as to the appropriate treatment (O'Loughlin et al., 2008). In 2008, MAF bought together a range of soil conservation practitioners for a workshop to develop a set of written guidelines to outline specifications for the treatment of eroding areas where poplar and willow pole planting could result in successful erosion control (O'Loughlin et al., 2008).

Although the performance of some poplar and willow soil conservation plantings has been less than optimal in the past, there is optimism among soil conservators that with appropriate species selection, planting spacing, installation, and maintenance, the erosion control performance of poplar and willow planting can be greatly improved. The effectiveness of poplars and willows for controlling erosion depends on the following:

- A thorough understanding of the type and severity of erosion as each erosion type requires a different approach.
- Matching the tree species to the land type, taking into consideration site conditions such as soil moisture levels and retention, wind, frost, and animal pest threats.
- Planting all relevant parts of the slope and not just the actively eroding part.
- Recognition that other erosion control techniques may need to be used in conjunction with planting (e.g. drainage, gully support, dams, and contouring).
- Continued maintenance of the plantings.

Many of the larger erosion features likely to be encountered in the LO3A area are beyond the scope of conventional pastoral-based erosion control measures and need a forest cover, often in association with gully planting, for stability (O'Loughlin et al., 2008). Where smaller linear gullies, slumps, and earthflows are identified as controllable by pole/wand treatment, the challenge is to reach agreement on planting and management strategies that will deliver a successful erosion control outcome for land classes identified in Gisborne District as LO3A (O'Loughlin et al., 2008).

Participants at the MAF workshop were evenly divided about whether to plant an area larger than LO3A for the treatment of gullies, earthflows, and slips and slumps (i.e. the surrounding catchment). There was a clear preference for the use of poles and wands for control of earthflows, and it was agreed that streambank erosion and incision in small, less active narrow linear gullies could be controlled by planting willows and poplars along the channel and banks. However, there was a lack of clear preference among practitioners regarding the planting densities of poles and wands for gully, soil slip, and earthflow, and no clear preference for poles or forestry for controlling slips and slumps, as site factors are a key determinant of their success. It was identified that there was a need to decide on criteria to define the limitations of pole/wand treatment of different erosion types, and to recommend appropriate planting densities/spacing for pole/wand planting.

Indicative planting spacings and planting locations recommended by workshop participants for various erosion types are presented in Table 2.22.

Table 2.22. Indicative planting willow and poplar spacings (from O'Loughlin et al., 2008).

Erosion feature	Spacing				Planting location
	Poles	Thinning	Wands	Thinning	
Moderate earthflow	7-10 m 10-12 m + blanking	10-12 m @ 10-20 yr None	5-7 m	10-12 m @ 10-20 yr	Unstable part of flow
Severe earthflow	7-10 m	None	5-7 m	None	Unstable part of flow
Moderate linear gully	6-8 m 7-10 m 10-12 m + blanking	10-12 m @ 10-20 yr None	2-4 m 5-7 m	10-12 m @ 10-20 yr	Watercourse Gully walls
Severe linear gully	6-8 m 7-10 m	None	2-4 m 5-7 m	None	Watercourse Gully walls
Moderate slump	7 m	10-12 m @ 10-20 yr	5 m	10-12 m @ 10-20 yr	Unstable part of slump
Severe slump	5 m	None	5 m	None	Unstable part of slump

All the planting schemes recommended by the participants of the MAF workshop are restricted to planting the unstable areas of existing earthflows, slumps, and gullies. However, research by Herzig et al. (2011) has shown that planting the entire catchment of existing gullies is preferable to reduce the amount of runoff reaching the gully, and to further stabilise the surrounding catchment by afforestation to prevent the initiation of new features.

O'Loughlin et al. (2008) concluded that willow and poplar pole planting were sufficient for erosion control if site factors that could potentially jeopardise successful establishment of willows and poplars were taken into account, and if plantings were established at the recommended densities/spacing and maintained appropriately. However, O'Loughlin et al. (2008) caution that gullies deeper than 5 m, on bentonitic or crushed argillite lithologies, are unlikely to be successfully treated with pole planting unless accompanied by afforestation or reversion of the surrounding watershed. Afforestation, with either pine or indigenous reversion, is the most practical option for stabilising large active gullies.

2.11.2.3 Comparative effectiveness of spaced pole planting & radiata pine

To compare the relative effectiveness of pole planting with planting radiata pine, the threshold root biomass required to provide effective soil reinforcement needs to be established for the two approaches. Knowles (2006) recently correlated East Coat poplar DBH and stems per hectare with root biomass, and found that mature poplar stands require a planting density of 70-100 sph to achieve the same root protection as closed-canopy pine forest, and that about 160-200 sph are needed to achieve quick stabilisation by younger trees on severely eroding sites. This is supported by the work of McIvor (2007) who showed that little fresh erosion occurred in the 2004 Manawatu storm event where planting densities on unstable ground exceeded 50 sph, but substantial erosion still occurred where planting densities were less than 50 sph. McIvor (2007) suggests that lower planting densities might be adequate because of the superior fine root mass of poplars. Final stand density needs to be at least 50-100 sph for adequate protection of soil, and that initial planting density in excess of 100 sph helps achieve stability at severely eroding sites. However, more information is required on poplar and willow root biomass development to compare the two methods with confidence.

2.11.2.4 Regeneration & reversion to scrub (kanuka and manuka)

Kanuka (*Kunzea ericoides*) and manuka (*Leptospermum scoparium*) covered about 12% of the Waiapu catchment in 1996 (Harmsworth et al., 2002), with about half of this on erosion prone land. A small number of research studies have been carried out on the effectiveness of mature kanuka and manuka for soil conservation purposes and for reducing erosion (Marden & Rowan, 1994; Bergin et al., 1995; Ekanayake et al., 1997; Watson et al., 1997; Rowe et al., 1999). This research showed that in mature stands, older than 15 years, kanuka and manuka were as effective for erosion control as *Pinus radiata* of 8 years or older.

Stem density of manuka and kanuka stands is usually around 20,000 stems/ha at 10 years and 3,000 stems/ha at 40 years, with kanuka often becoming dominant. Landslide density has been shown to decrease greatly where mature stands of kanuka and manuka are present; landslide density was often 65% less than pasture at 10 years, and 90% less at 20 years (Bergin et al., 1993, 1995). Stands intercept up to 42% of gross rainfall, considered high in relation to other vegetation types, which indicates the effectiveness of kanuka/manuka for intercepting rain during intense rainstorms and protecting erosion prone land (Rowe et al., 1999). Kanuka/manuka also has very high below-ground biomass (Ekanayake et al., 1997), with tree roots being a major contributor to soil strength and slope stability. This is due to the presence of a dense fine-root network with a higher root tensile strength than *Pinus radiata* (Ekanayake et al., 1997, Watson et al., 1997). Mature stands are about 16 times more effective than pasture and young pine trees (<6 years old) in preventing the initiation of landslides during periods of extreme rainfall (Marden & Rowan, 1994; Bergin et al., 1995).

Gully erosion in the Waiapu catchment also occurs in undisturbed natural forest. Parkner et al. (2007) recorded active gully systems within natural forest in the Mangaoporo catchment that formed in response to major storm events between 1946 and 1997, primarily, following Cyclone Bola in 1988. Despite five significant rainfall events after 1988, no further gullies developed and all gullies showed signs of recovery in response to recolonisation of the bare slopes by indigenous vegetation. In 1988, 21 ha, or 3.3% of the 14.1 km^2 study area, was affected by gullies. By 1997, the total area of active gullies had reduced to 13.2 ha (Parkner et al., 2007). Parkner et al. (2006) concluded that under normal climatic conditions, an undisturbed natural forest cover can protect against the development of gully systems and accelerate the stabilisation of gullies.

2.11.2.5 Check dams

A check dam is a small dam, which can be either temporary or permanent, built across a minor channel, swale, or drainage ditch. They can reduce erosion and gullying in the channel and allow sediment to settle and accumulate behind the dam. They also lower the speed of water flow during storm events. These dams are usually used only in small, open channels that drain small catchments ($<0.040\ km^2$); and usually do not exceed 0.6 m high. Check dams require periodic removal of sediment, which is often difficult.

Although check dams have been successful at reducing downstream sediment supply in some French rivers when used in conjunction with gravel extraction (Liébault et al., 2005), early attempts at using fascines and check dams for on-site erosion control in the Waiapu were only successful for smaller and linear-shaped gullies but not for controlling larger gullies or gully-complexes (Marden et al., 2008). Check dams can temporarily reduce sediment supply to downstream reaches in small streams, and prevent downcutting in small linear shaped gullies, but do not address the rate of sediment supply to the channel from erosion. There were historically large debris dams used to trap sediment from larger gullies in the Waiapu, but these were unsuccessful. The high sediment supply rates in the Waiapu catchment preclude their use because sediment would rapidly swamp check dams and render them useless. Check dams and debris dams are rarely cost effective today.

2.11.3 Main points & lessons learnt

- Afforestation has been the most effective mechanism to stabilise actively eroding gullies and to reduce sediment production.
- Afforestation efforts to date (1969-2008) have reduced the sediment yield from gullies in the Waiapu catchment by 17% from what it would have been without afforestation.
- The greatest potential for reducing sediment yield from gullies is to target afforestation to the gullies themselves, a relatively small proportion of the catchment area.
- If all gullies were to be forested by 2010, the sediment yield from gullies could be reduced by half (from 22 Mt/yr to 11 Mt/yr) by 2050, but if afforestation efforts were terminated today, and new gullies were also left untreated, the sediment yield from gullies would double (to 45 Mt/yr) by 2050.
- To achieve effective erosion control of gullies treatment of adjacent areas is often required.
- Afforestation of MAF target area is more effective in reducing sediment yield compared to GDC's LO3A, because MAF target area incorporates more gullies and involves planting of a greater proportion of the catchment surrounding each gully.
- Despite about 54,000 ha of afforestation in the Waiapu catchment, gully area has increased by 17% between 1957 and 2008 from what it would have been without afforestation because new gullies initiating in highly erosion prone land that remains in pasture, and untreated gullies continue to increase in size.
- Willow and poplar pole planting are sufficient for erosion control if site factors that could potentially jeopardise successful establishment of willows and poplars were taken into account, and if plantings were established at the recommended densities/spacing and maintained appropriately.
- Gullies deeper than 5 m, on bentonitic or crushed argillite lithologies, are unlikely to be successfully treated with pole planting unless accompanied by afforestation or reversion of the surrounding watershed.
- Manuka and kanuka are effective at reducing erosion. Mature manuka and kanuka stands, older than ≥15 years, are as effective for erosion control as *Pinus radiata* of 8 years or older. Landslide density under manuka/kanuka was 65% less than pasture at 10 years old, and 90% less at 20 years old.
- Check dams and fascines are unsuitable for reducing downstream sediment supply in the Waiapu where the sheer volume of sediment supplied to the channel

would overwhelm structures and render them useless. They also do not address the rate of supply of sediment to the channel.

2.12 Knowledge gaps & recommendations

Although there has been a substantial volume of research carried out in the Waiapu catchment to date, as evidenced by the large number of references in this review, there remain important gaps in our knowledge pertaining to the future management of the catchment. In general, there are knowledge gaps in the scientific understanding of erosion and sediment dynamics in the catchment, (connectivity and lags) and downstream effects, including hill slope-channel linkages. These are key to understanding the impacts of erosion mitigation measures and their role in achieving the desired state. There are also gaps in the application of scientific knowledge in management and planning strategies, and in effective community engagement processes between research providers, GDC, Ngāti Porou, and other landowners. The gaps in existing knowledge listed below limit our ability to identify the amount, mix, and spatial distribution of erosion mitigation measures (afforestation, reversion, and wide-spaced tree planting) required to improve geophysical conditions in the catchment sufficient to address aspects of a 'desired state‗as identified by Ngāti Porou.

Based on the review of relevant literature and consultation with researchers who have worked in the Waiapu catchment, the following were identified as knowledge gaps and areas for future research. These are listed in order of priority:

1. The rates of erosion and relative sediment contribution by processes other than gully erosion under different land uses and land management practices have not been sufficiently quantified. Research should be undertaken to achieve this. These other processes account for 51% of the sediment yield.
2. The impact of reduced hillslope sediment supply on river sediment transport. Specifically, how much afforestation, reversion, and wide-spaced tree planting is required, and what is the interval or lag time, to affect a switch from aggradation to incision, and what is the rate at which it will propagate from headwater streams to the main stem of the Waiapu River are unanswered questions. This rate may also be influenced by the volume of sediment stored in the Waiapu River network, which is also unknown. The absence of cross-sections in many tributary streams and the irregularity of cross-section surveys currently limit the ability to address this issue. A network of adequately spaced and regularly surveyed cross-sections is essential to better understand the dynamics of bedload transport and to link patterns and rates of aggradation and incision to land use changes.

3. The impact of increased sediment supply to the river channels on the availability and quality of freshwater habitats for indigenous and introduced fish species (e.g. suitable sites for spawning, incubation of eggs, and rearing of young) is largely unknown. Data on benthic invertebrates are lacking. The co-benefits likely to accrue from land use change (revegetation) on stream habitat and the hydrological regime have yet to be adequately quantified. Appropriate research and monitoring should be undertaken to address these knowledge gaps.
4. The role and influence of riparian zones on stream health and for stream restoration is currently not sufficiently well understood. Further research on this is required.
5. Implementation of a monitoring strategy is necessary to identify sedimentation patterns and associated changes in marine fauna. Sufficient information is not currently available.
6. The effect of declining sediment supply and future storm events on channel morphology (width and shape) is currently not well understood. Changes in channel morphology will have an effect on future flooding, sedimentation, bank erosion, infrastructure (bridges) and instream habitat values. Further research is required to address this issue.
7. The impact of future aggradation/incision rates in different reaches and tributaries on infrastructure such as bridges and roads is currently not well understood. The majority of existing cross-sections are located in the two worst eroding catchments and reflect GDC‘s concern of damage to several bridges. Loss of access affects economic viability, social cohesion and is an ongoing cost. Establishment of additional cross-sections is needed.
8. The relative effectiveness of vegetation in controlling the different types of erosion has been better quantified for exotic forestry, principally *Pinus radiata*, and indigenous reversion than for wide-spaced tree planting and other exotic species. A greater research effort is required to quantify the effectiveness of wide-spaced tree planting (including willows, poplars, and indigenous species), particularly their optimal spacing, root reinforcement properties, and management requirements, over a range of event magnitudes and for the different erosion types.
9. Further research into the effectiveness of indigenous reversion as a means of erosion control is required.
10. The impacts (and uncertainties) of forecast climate change (rainfall and storm magnitude/frequency) on hill slope erosion, and river behaviour and sediment transfer are currently not well understood or quantified. Increase in storm rainfall

will cause erosion and sediment yield to increase. Further research is required to address this issue.

11. The relative contribution of sediment yield to bedload and suspended load from different land uses and land systems, and how this might be affected by land use change and/or gravel extraction has not been adequately quantified. Further work to address this is required.
12. Little analysis has been performed on existing rainfall, river flow, and suspended sediment data. A detailed analysis and review of this data would be useful to establish whether more data is required, the usefulness of the data currently being collected, and what new data (if any) might be more useful.
13. The impact of a large magnitude earthquake on hill slope erosion, and river behaviour and sediment transfer is not well understood. Further research is required. However, this can only be assessed after an event.
14. Knowledge of the properties and distribution of soils in the hill and high country areas of Waiapu catchment is currently limited. While soils of the floodplain and low lying areas have been mapped in sufficient detail this needs to be extended to the rest of the catchment. This is important for improved land use sustainability and productivity.

2.13 Summary & conclusions

The Waiapu catchment is located in a dynamic tectonic and climatic setting. Recent and extensive deforestation has exacerbated the high natural rates of erosion and sedimentation. The response to deforestation has been rapid and pronounced. Research to date has provided some insight into landscape controls on sediment generation and transfer in the Waiapu catchment following deforestation. However, much of the research has been focused on gully erosion. Extensive gully erosion commenced within one or two decades, and now accounts for 49% of the annual suspended sediment yield of 35 Mt, which is more than twice that of the adjacent Waipaoa River, the next highest yielding New Zealand River, and nearly ten times that of the Manawatu River. Similarly, channel responses to sudden fluctuations in sediment supply have been rapid with channels aggrading, and particularly in the lower reaches, widening markedly. Recent research also shows that land use/vegetation change is the most effective method of controlling erosion. Modelling indicates that planting all ECFP ‗target land' by 2020 is more effective than planting all LO3A land, and the earlier this is achieved the greater the reduction in gully-derived sediment yield. However, sediment yield from gullies will still increase due to unplanted gullies, unstabilised gullies, and new gullies on untreated areas outside the ECFP target land. The most effective afforestation strategy is to plant all gullies in the catchment, (including newly formed gullies), and again the earlier this is achieved the greater the reduction in sediment yield. Even then, sediment yields will remain high (similar to present), as a result of gullies too large to stabilise, sediment stored in river beds, and other erosion processes. A more detailed summary of the main findings is given at the end of each section of the review.

Major knowledge gaps include the amount and location of afforestation that will be required to reduce sediment input to a level where the land and rivers are again able to meet the needs of Ngāti Porou, and specifically the time it will take before the signs of recovery that are starting to be seen in the upper tributaries are translated downstream to the lower reaches of the Waiapu River. There remain important gaps in our knowledge pertaining to the future management of the catchment, not least to the application and implementation of scientific knowledge, and the social aspects of implementation and collaboration between CRI's, GDC, Ngāti Porou and other local landowners. Continued monitoring of vegetation cover, gully information, sediment yields, river cross-sections, water quality, and flora and fauna associated with freshwater and marine ecosystems is recommended to assess future catchment conditions, and to assess the effectiveness of land use changes and erosion mitigation measures. It is also recommended that the impacts on the catchment of future large perturbations, such as storms or earthquakes be assessed.

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3 Literature review & kōrero – impacts of land use change & erosion on Ngāti Porou in the Waiapu catchment

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3.1 Introduction

This literature review considers the direct and indirect social, cultural, and economic dimensions of erosion and land use change with reference to Ngāti Porou and the East Coast and is based primarily on several major ethnographic studies undertaken in the region. The structure of the review is based on the outcomes of the work of Te Haeata, the sub-committee responsible for the supervision of the Ngāti Porou Treaty of Waitangi Settlement Negotiations with the Crown. Te Haeata reports to Te Runanga O Ngāti Porou Board of Trustees. To support this process Te Haeata held three Ngāti Porou Wananga in February and March 2009. These hui sought to identify a prioritised set of issues that are key to achieving Ngāti Porou aspirations and vision. Te Haeata described ten aspirations for Ngāti Porou as follows:

- Strong identity – whakapapa.
- Ngāti Poroutanga.
- Employment & wealth creation (economic).
- Te Reo & tikanga.
- Whanau.
- Mana Motuhake.
- Connectedness.
- Matauranga.
- Clean environment.
- Infrastructure.

The review seeks to build baseline knowledge, using the above ten aspirations, that may be used to describe an aspirational ‗desired' state for the catchment and its people, with a focus on erosion.

The authors would like to acknowledge the immense contribution of Garth Harmsworth and Tui Warmenhoven (Harmsworth et al., 2002), whose work underpins much of this review.

3.2 The impact of land use change & erosion on Ngāti Porou in the Waiapu catchment

The impact of land use change and erosion on Ngāti Porou in the Waiapu catchment is presented as a kōrero within the ten point aspirational framework developed by Te Haeata. Capturing the social, cultural, and economic status of the Waiapu will help in developing the aspirations and visions for Ngāti Porou and the Waiapu catchment.

3.2.1 Strong identity, whakapapa, & Ngāti Poroutanga

The land, the river, the forests, the mountain, the ocean, and the life and history associated with them are intricately woven together in the nature of what it is to be Ngāti Porou (T. Warmenhoven, pers. comm. 2011). The land and Ngāti Porou are part of the same.

> *"Ko te whenua te wai-u mo nga uri whakatipu."*
> *In English this means „mother earth, through her placenta, provided nourishment and sustenance for her offspring." (Harmsworth et al., 2002, p 19).*

3.2.1.1 The land

The Waiapu catchment is located in the north of the Gisborne-East Coast region of New Zealand. A description of the catchment is given in Harmsworth et al. (2002). In summary, the catchment covers an area of 1,734 square kilometres and is centred on the township of Ruatoria. The population inside the catchment boundary is predominantly Māori. The catchment includes the Waiapu River (total length ~130 km) which flows east and northeast to the Pacific Ocean, and Mt Hikurangi (1,752 m). The Waiapu River is formed by the joining of the Mata and Tapuaeroa Rivers from the headwaters of the steep Raukumara range. Both the river and the mountain are spiritually and culturally significant to Ngāti Porou who are the largest Iwi on the East Coast. The Ngāti Porou tribal proverb of identity is:

"Ko Hikurangi te maunga
Ko Waiapu te awa
Ko Ngāti Porou te Iwi."
In English this means "Hikurangi is the mountain, Waiapu is the river, Ngāti Porou is the tribe." (Tamati Muturangi Reedy., 2011, www.teara.govt.nz/en/Ngāti-porou/2).

Rau (1993) describes the Waiapu catchment prior to major European settlement as appearing to have been well populated with local people enjoying a high standard of living compared with other regions of New Zealand. The settlement in the Waiapu valley and land use change is described by Harmsworth et al. (2002). They describe that Māori have existed in the Waiapu valley for hundreds of years and settlement in the area was widespread up until the 1880's. At this time early European occupation of land started (between 1870 and 1880) in the very north of the Waiapu district. The following 140 years resulted in the traditional culture, and the environment that was part of this culture, to undergo great change. The increasing European presence in the Waiapu catchment resulted in the start of extensive and quite rapid deforestation and changes to pastoralism with sheep and beef farming, dairying on lowland areas followed by a return to sheep, and extensive planting of exotic forests. In addition, where there were once vast cultivations that had been documented by European explorers and missionaries, there is now only limited cultivation on the flats (Harmsworth et al., 2002).

Beckwith (2007) describe the lands about the Waiapu Valley as an ideal area to settle due to the fertile land, abundance of food from the cultivation of kumara and taro, and from both the forest (including birdlife, rats, tawa berries, karaka berries, tāwhara and fern root) and the sea (providing kina, pāua, kuku, and pipi). She describes that in the beginning of the 19th century the valley was well populated and Ngāti Porou lived in large villages and marae along valleys and streams, and on the coast (including at Tikapa and Te Kautuku). She stated that every small hill could be found to be under cultivation of some degree with much of the land cropped for potatoes and maize.

An intensive survey for the New Zealand Historic Places Trust as part of a programme for the identification and preservation of archaeological sites in 1979 (Leahy and Walsh, 1979 described in Beckwith, 2007) confirmed that there was considerable settlement along both sides of the Waiapu River Mouth and that the river system probably served as a communication link. The sites were spread out with the highest density along the south bank of the River Mouth. Beckwith (2007) describes how pits were a common feature in the archaeological survey with some pits present in relation to a pā while others were isolated features and she mentions that some may have been damaged by animal or vehicle tracks, or erosion, or were hidden amongst rampant gorse or scrub.

Beckwith (2007) describes that Māori know the land well, can recall the history of the area with passion, trepidation, and respect, and remain fiercely protective of the land. There are sites of importance to Māori in the Waiapu such as the Mountain range of Te Kautuku which acts as a navigation point for fishermen and travellers, and also comprises a plateau that was once a famous battleground known as Te Nuku, which has seen many tribal wars (Beckwith, 2007). There are many historical areas present in the Waiapu, where blood has been spilt in territorial defence and where the bones of buried ancestors lie still, of which a majority of this area has in general remained in Māori ownership and has been farmed by different members of local families (Beckwith, 2007). There are also sites that once hosted businesses, for example Beckwith (2007) described Port Awanui as a once booming little port on the south side of the river on the coast, with many businesses including a courthouse, police station, and post office. Although there has been change, the Waiapu continues to play a vital role in the lives of Ngāti Porou (Beckwith, 2007).

Land use change in the Waiapu catchment over the past 130 years has resulted in the very fragile landscape eroding under pasture, increasing the flooding risk and sediment supply to streams and rivers, largely determining the present state of health of the rivers and landscape (Harmsworth et al. 2002). Harmsworth et al. (2002) describes erosion as a significant and ongoing problem and land use planning and resource management initiatives to reduce erosion have been initiated. For example, the planting of exotic forest for erosion control began in the late 1960‘s. The land use planning and resource management initiatives relating to erosion control (noted in Appendix 5) have been largely driven by non-Māori groups which have resulted in the community to complain of government interference with many of these land use schemes (Harmsworth and Warmenhoven, 2002).

3.2.1.2 The river

The Waiapu River is one with Ngāti Porou. The Waiapu river valley is referred to by Ngāti Porou in a tribal saying:

> *"Hoake taua ki Waiapu ki tatara e maru ana."*
>
> *In English this means "Let us shelter under the thick matted cloak of Waiapu."* (Tamati Muturangi Reedy., 2011, www.teara.govt.nz/en/Ngāti-porou/2).

It is difficult to underestimate the importance of the Waiapu River to whakapapa and the identity of the people (T. Warmenhoven, pers. comm.). In the past, the river provided an abundance of food to the people, including mussels, tuna (eel), variety of freshwater and saltwater fish (T. Warmenhoven, pers. comm.), and enabled the transportation of resources (Harmsworth et al., 2002). Harmsworth et al. (2002) describes that during the past 100 years the rivers and streams have deteriorated markedly in the catchment and locals consider that if the water is drinkable and no adverse health effects result then it is good quality. They quote that some have said:

> *"the water here is fine"; "there, look and see, the people here are still alive…". (p 55).*

The ability to find food is a vitally important aspect of Maori knowledge. The river and its associated tributaries and wetlands have supplied the different parts of the local community with grayling, kokopu, inanga, and watercress. Harmsworth et al. (2002), refer to a noticeable decline in the distribution and abundance of these resources with many local people blaming the removal of natural forest and the resulting increase in sediment in the river. Harmsworth et al. (2002) described how the catchment contained abundant resources of lamprey and both species of eel (Tuna) and how they formed a major part of the staple diet of many Ngāti Porou. There still remains community held knowledge of eeling and the techniques used in preparation, storage, and consumption. As with other species of fish, eel populations are thought to have declined over recent years largely as a result of sediment deposition and changes in the characteristics of the river.

Harmsworth et al. (2002) refer to the importance of water quality or the health of the water (mauri, ora, oranga) to tangata whenua emphasising a perceived decline in river quality over the last century. They refer to a level of acceptance on the part of some people over the state of the river. Some consider that the river may have been in a worse state if agriculture were to be more intensively practiced in the catchment. Harmsworth et al. (2002), also describe how many make an association between native forest cover and the provision of a sustained water supply for livestock and communities alike.

Most streams and rivers are used by farmers as a water supply for livestock which are allowed to have direct access to the water (Harmsworth et al., 2002). However, there are some exceptions in the headwaters where the water quality is considered to be in a natural state (Harmsworth et al., 2002). Moreover, there are many springs on the hillsides and in valleys of the catchment; many of which have cultural and spiritual significance as well as providing a reliable source of water during times of drought (Harmsworth et al 2002). The Waiapu River also offers gravel beaches that are currently a primary resource for roading gravel (Harmsworth et al., 2002).

3.2.1.3 Coastal environment

It is likely that high sediment loads will be negatively impacting on inshore and offshore fisheries and traditional activities of Ngāti Porou. Harmsworth and Warmenhoven (2002) refer to anecdotal evidence which points to a large sediment supply affecting the coastal and marine environment. Figure 3.1 below highlights a number of sites recognised as possessing Territorial Customary Rights (TCRs).

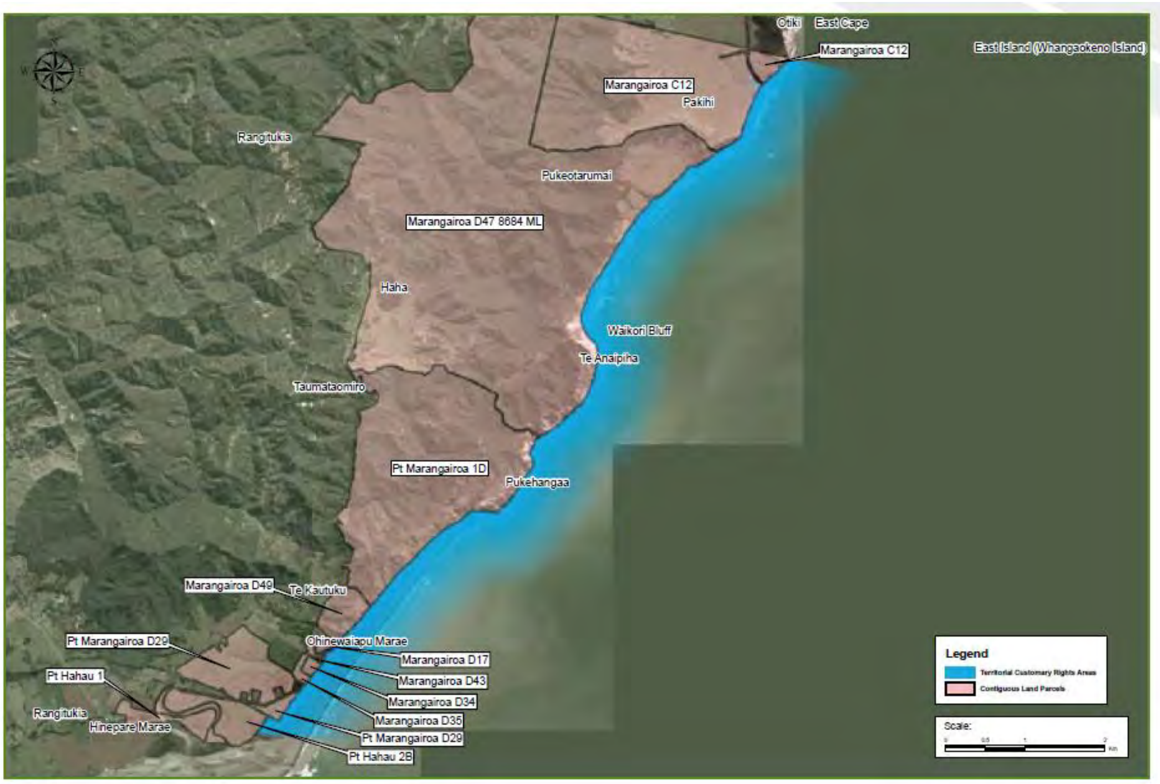

Figure 3.1. The territorial customary rights areas in the Pakihi to the northern side of the Waiapu River (reproduced from Final Ngāti Porou Foreshore and Seabed Ratification Information Document, August 2008).

Langer and Tomlinson (2003) quote a respondent from the rural Māori roll in their attitudinal study on the East Coast as saying:

> *"Waste from pine slips into the river, drags into the sea and kills off seafood. Riverbeds are getting silt deposits in them. Heaps of damage."* (p 29).

Similar observations on Kai Moana (seafood) were made by Harmsworth et al. (2002) where the loss of both shellfish and fish at Rangitukia beach from the ngutu awa (river mouth) to Te Whanga o keno was attributed to the silt output at the ngutu awa, as well as to over-harvesting. They also quote one kaumatua from Tikitiki who recalls catches of kahawai being freely distributed:

> *"Whoever went used to deliver on their cart, stop at every gate and hang some fish on there for those who never used to go out, for those who never went to fish… but nowadays there's not much of that going on… I don't think that I would like to have anymore kahawai with all the muck that's going into the river." (p 59).*

Harmsworth et al. (2002) describe that in the past, fish were plentiful and Kahawai were generally caught by net fishing (hao ika), or without a net when the sea was calm near or in the ngutu awa, and by using a longer net (―Kupenga koko kahawai") to scoop up shoals while working toward the Waiapu river mouth. They describe that fishing was dangerous and restricted to males, who often fished naked, and generally women were forbidden to go near the area. Tamure were also present at the ngutu awa as well as patiki or flounder depending on the tide and time of year, and Kanae or mullet. In addition, there were plenty of fish caught from Whakori to Te Whanga o Keno to Pohautea and over to Awanui (Harmsworth et al., 2002).

Although Kahawai and kanae are currently reported to be returning to the ngutu awa of the Waiapu they are scarce, particularly after large magnitude storms such as Cyclone Bola, and locals believe the reduction in numbers can be attributed to the high sediment output at the ngutu awa (*Harmsworth et al., 2002)*:

> *"Kahawai used to come in great numbers to the ngutu awa, now their numbers have declined dramatically because the Waiapu has filled in with sediment." (Pohatu & Warmenhoven 2000, in Harmsworth et al., 2002, p 59).*

3.2.1.4 The People – health of the environment & wellbeing of Ngāti Porou

Ngāti Porou has a deep connection with the land and the environment. Harmsworth et al. (2002) quote a number of Ngāti Porou respondents as follows:

> *"The river is our taonga and our life essence."* (p 28).
>
> *"The health of our river depends on the hapu that inhabit those valleys that fed into the Waiapu. And if their health is not good, neither is the health of our river."* (p 28).

Kai (food) that we put into our mouths, our hinengaro and our wairua. You have to feed all three. They must all be healthy…. Health is nurturing or feeding these things. (p 28).

Harmsworth et al. (2002) also emphasise that the Waiapu catchment is of great spiritual, cultural, physical, and economic significance to Ngāti Porou and the health of the catchment extends much further than the physical elements of the landscape. They explain that:

"The whenua, including all waterways, is Papatuanuku, the nourishing provider, and the protector of all living things. Together with Ranginui, the air we breathe, she allows us to use and exploit elements of her that are necessary for our survival. Through life we remain her dependent offspring and in death we return to her." (p 28).

And quote a local as saying:

"She is a living entity, as everything is life, whether it be plant life, or human life, or mother earth. When you look back in our stories and histories, the earth has always been our mother and nourishes us. That's because we are part of one and the same in our creator." (Harmsworth et al., 2002, p 28).

The Waiapu catchment has been described by Harmsworth et al. (2002) as highly degraded and modified and exhibits an extensive and serious erosion problem. The erosion in the catchment has resulted in the build-up of sediment in many of the rivers and consequently they are classed as highly degraded (Harmsworth et al., 2002). Harmsworth and Warmenhoven (2002) describe how erosion reflects on how some Ngāti Porou feel they may be becoming as a people:

"We are losing our mana. The river is eating away at the land. Without this land we are nothing." (p 7).

"Today, tangata whenua are becoming increasingly aware of past errors regarding misuse and mismanagement of land. Many agree that repetition must be avoided in future planning. Our people died protecting our land. This place would have been beautiful. Today we are trying to save what we ruined. We have to be very conscious and aware of how we live in our environment…. Some people see [sic] the land to make dollars, money.

That is not necessarily applicable to all ecosystems. Some areas are for that purpose. Not all areas are for exploitation." (p 7).

"It's just been take, take, take and there's been no give. And when there's no give, that's what happened with mother earth (papatuanuku). That's the only way she can say „Hey, enough's enough', you know. The erosion, the floods, the kai is disappearing." (p 7).

Langer and Tomlinson (2003) found similar views expressed by a rural Māori respondent who blamed forestry for:

"Eroding culturally significant sites (Wāhi Tapu). Have heard of some chemicals in the forest which have a drain-off effect into our waterways." (p 29).

Harmsworth and Warmenhoven (2002) also suggested that a high degree of connectivity is made in all Ngāti Porou definitions of wellbeing between spirituality, values, and ecological health. They also argue that the understanding of health extends:

"Beyond the physical environment into the mind/psyche, the soul, and the spirit. As the name suggests, whenua and tangata are inextricably intertwined, and when one of these becomes unbalanced, the other equally suffers." (p 7).

The health of the rivers and land all directly impact on a community's health of which environmental degradation from erosion all impact on the ability of Ngāti Porou and the Waiapu catchment community to provide for the future with respect to (for example) the following values; clean drinking water, recreational sites, and environment and biodiversity (Harmsworth et al., 2002). When the Gisborne–East Coast region is compared with the general New Zealand population, as discussed by Harmsworth et al. (2002), a large number of socio-economic issues and disparities are identified for example; health, housing, high unemployment and low household income, further supporting the connectivity between the health of the land and its people.

3.2.1.5 The forests

Ngāti Porou and perspectives on the clearance of the catchment

Before deforestation the indigenous forest cover in the Waiapu catchment was reported to be about 80% to 90% in 1840, based on historic records (Harmsworth et al., 2002). The mature indigenous forest was rich in natural flora and fauna (Harmsworth and Warmenhoven, 2002). Large scale deforestation began about 1890 by European settlers to establish pastoral farming with the main period of deforestation and burning between 1890 and 1920 (Harmsworth et al., 2002). Today only 21% of the indigenous forest is present, of which much is confined to steep mountain ranges (Harmsworth et al., 2002). The deforestation resulted in greatly increased erosion and sediment transfer and the present extensive and serious erosion problem can be attributed to the deforestation and a large number of subsequent storm events and floods in 1916, 1918, 1938, and Cyclone Bola in 1988 (Harmsworth et al., 2002).

Harmsworth et al., (2002) reported the opinions of tangata whenua on the large scale deforestation for pastoral farming and following erosion problems:

> *"When the trees were cut the land began to move, there those are the ones that had the most slips, Waingakia, Mata, Ihungia and Tapuwaeroa. That place is filled with rocks from the slips, it is the same with the Waiapu; it has been filled in. The stations there have all gone, there are blocks of land that are there in the Waiapu."* (Harmsworth et al., 2002, p. 48).

Harmsworth et al. (2002) commented about the lack of spiritual connection with the whenua (land) in particular with much of the bush felling around the Tapuaeroa and Mataa sub-catchments that was carried out by outsiders experienced in clearing bush.

> *"A lot of the bush they had burnt down, they didn't even bother to take the best trees out; they just burnt everything just to get rid of the trees and fence it off and put stock there." (Harmsworth et al., 2002, p 48).*

With the loss of native forests went knowledge of the resources they contained. In order to recover this lost knowledge, Ngāti Porou relies on Tuhoe (T. Warmenhoven, pers. comm.).

Background to forestry in the region

A summary of the emergence of plantation forestry on the East Coast is provided by Tomlinson et al. (2000). Plantation forestry in the Gisborne-East Coast region arose during the 1960's as part of New Zealand's second forestry planting boom to control erosion and to increase employment in the area. There were few associated infrastructures for plantation development and the forestry industry has gradually developed in the region. This resulted in the continued management of the forests by the New Zealand Forest Service (NZFS) until the late 1980's, after which a new era of privatisation emerged.

Harmsworth et al. (2002) reports that from the 1970's, the catchment community combined to use forestry initiatives to reduce erosion and for a short time in the 1980's forest planting was expanding at 6000 to 7000 acres a year over the entire East Coast. Today exotic plantation forests (*Pinus radiata*) cover 26% of the catchment (Harmsworth et al., 2002).

Community views of forestry

Giera et al. (2007) described in a case study on the East Coast Forestry Project, that there was a negativity felt towards forestry and the perceived political interference in the design and scale of the Project with inadequate local consultation. They also described that the negativity towards commercial forestry arose largely due to the collapse of two large forestry companies during the late 1990's and the financial hardship that resulted.

Warmenhoven (2004) found that members of the Ruatoria community had quite forthright views about the expansion of forestry in the area:

> *"The major change is that there are more pine trees. There is a lot of erosion here which doesn't help and that is one of the ways to stop it, is by planting Pinus radiata trees."* (p 12).
>
> *"Yes [forestry], it is starting to intensify in a lot of our farms now, and a lot of the poorer areas are either locked away or regenerating and some of it has gone into forestry."* (p 12).
>
> *"Yes, this land is deteriorating and we have seen a lot of regrowth and of scrub and also a lot of land has shifted to forestry use."* (p 12).

Tomlinson et al. (2000) found a similar story being told citing accounts of people moving to Gisborne from rural areas in the search for work as farms were converted to forestry. Some people retrained for forestry work resulting in much of work force based in Gisborne, and working in the forest industry. They quote a regional opinion leader as follows:

> *"The biggest… change I notice is that the labour force is mobile, whereas before it was residential. That is hugely significant in this region. It impacts heavily on the infrastructure of the small rural town. The dollar that was spent there before – Ruatoria, Te Araroa, Tikitiki, Tokomaru Bay, Nuhaka, Waiponga – those dollars are now spent in Wairoa and Gisborne. A large proportion of the mobile workforce takes their pay-packet past those places and back to the centres. The impact of that is visible on the eye. If you were to drive around you would see the derelict schools, or where they have been sold. You will see garages for fixing motor vehicles, that's gone. You can't get a haircut up the Coast. You have to go somewhere else for that. Butchery shops, funnily enough, they disappeared. General stores disappeared. Where you can buy petrol at the general store they disappeared."* (p 21).

Tomlinson et al. (2000) also explains that many feel that forestry has disrupted the life of farming and the knowledge sharing that goes with those participating. They quote a non-farming person on the East Coast:

> *"Even the workers on the farms. Their kids grew up on the farms. They learned about farming as they went. By the time they left school they had the skills, so they got a job. They learned how to shear a sheep and milk a cow before they left school. But, that doesn't happen with forestry. Even if the father has got a job, he can't take the children with them. So, they don't learn."* (p 22).

Langer and Tomlinson (2003) undertook a series of preference studies and found that many Ngāti Porou had concerns about forestry. Many of the following comments from Langer and Tomlinson (2003) capture themes that affect the aspirations Ngāti Porou have for their future:

> *"Pine forests will cause a lot more erosion. Cause run-off waste. They don't fall like natives. If forests were growing with natives it would be all right."* (p 19).

"[Pine forests] destroys our precious and sacred land. Then when they grow and are being felled, the land looks bare and raped." (p 19).

"The land is being abused. Nothing else grows." (p 19).

"Takes too long to reap benefits. By the time our mokopuna come along there will be pine all around and not everyone will be able to work it. Also pollutes the land. The place for forestry is where slips and erosion are. Not on good farmland. The chemicals are going into our rivers, polluting our water, killing our wildlife – farmers too." (p 19).

"No more good land should be taken up in forestry. Usurping the mana. Land is mana to Māori. Should have a certain level that forestry develops to unless there is 100% gain for Ngāti Porou. Too many men from outside." (p 28).

Tomlinson et al. (2000) reported a number of positive views on forestry from individuals in the Gisborne-East Coast region as follows:

"Forestry has kept Gisborne going… The forestry feeds into the port. The port employs people. There's hundred of businesses around town that have flourished since the forest industry came into this area. New businesses, existing businesses. People who have set up services specifically for the forest industry. Perhaps they would have left town if they didn't have that to do. Perhaps they would have just decided to take the benefit and sit back. As far as forestry is concerned I think it is positive for the region… Look at Ngāti Porou. They have got themselves so highly organised that they are able to go into multi-national deals with the likes of Hansol to buy previously owned farmland and put it into pines, and say „this is an investment in the future of our people'. And, that in itself is a major undertaking. Positive. Definitely positive." (p 15-16).

"There have been happy people that have found employment. They have got themselves on their feet. They are no longer frustrated. You have incidences where the kids have grown up in an unemployed family, the son has got a job. It has positives." (p 16).

"What the region requires now is patience to see the benefits. When this does occur the region will see more of the things they desire now, that is especially that there will be more processing." (p 16).

Community views on the restructuring of the Forest Service & Ngāti Porou

The New Zealand Forest Service (NZFS) was sold and privatised in the mid 1980's (Harmsworth et al., 2002). Tomlinson et al. (2000) commented on the feeling of contempt and distrust of the forestry industry as a result of the disestablishment of the NZFS and forestry privatisation. They refer to the thoughts of a long time East Coaster:

> *"When the forestry came in there were great hopes with the government run forestry scheme, right up to 1983. Then the Labour government decided to sell the forests. That was a major error in my opinion, as far as employment. A lot of Māori had come back here and they came back from the cities, they'd taken out a mortgage and basically they had lost everything. They built a home and suddenly there was no work."* (p 54).

Tomlinson et al. (2000) suggests that the feelings of contempt and distrust toward the forestry industry may have resulted in this attitude being passed to the next generation who therefore don't want to be involved in forestry work. They make reference to a community worker, with experience on the East Coast and in Gisborne as saying:

> *"First of all, the people have a chip on their shoulder about the government shutting down forestry in the first place. So, how are we going to get them to go back and say that it is not going to happen again…?"* (p 54).

> *"They have soured people. They have been there done that and don't want to go back. They would sooner sit at home and collect their dole money."* (p 54).

In addition, Tomlinson et al. (2000) describes that with the privatisation of forests and changes in the way the forests are managed by current forestry companies has resulted in a gap in the expectations of the employers and the workers. They describe that the workers familiar with the way things were under the NZFS expect that they deserve a certain level of consideration However, the employers view it differently which results in misunderstandings that create a barrier to some people coming back into forestry.

A glossary of Māori and Ngāti Porou terms is given in Appendix 6.

3.2.2 Employment & wealth creation (economic)

McElwee (1998) focuses on the economic, environmental, and social impacts of afforestation on hill country farmland on the East Coast. In this, farm and regional-scale afforestation of pine and wide-spaced planting with poplars were modelled. While there was evidence at the farm scale that both afforestation options offered a greater Net Present Value than pastoral farming, it was also highlighted that forestry provides more environmental benefits in terms of soil protection and social benefits through increased employment in the area (McElwee, 1998).

More recently, Rosser et al. (2008) completed a literature review and catalogue of physical resource information for the Waiapu catchment on the East Coast. This looks in great detail at the geophysical factors associated with the catchment and therefore does not get into the socio-economic effects that severe soil erosion and sedimentation can have on communities. This work is important when comparing the levels of erosion and sedimentation in the area with socio-economic trends. Also outlined in this work are the government initiatives that have been used to date to combat the issue of erosion, through afforestation, in the catchment (Rosser et al., 2008).

While there is a wealth of information available on the geophysical state of the Waiapu catchment and the East Coast, there is a lack of up to date information on the associated state of the communities within the catchment. Much work was done in the lead up and following the East Coast Project in the 1980‘s and early 1990‘s but it was thought that the focus of the project was too convoluted and thus the project was refocused on stopping soil erosion. Since then there has not been the same effort into documenting socio-economic issues associated with soil erosion. A study into the socio-economic effects of afforestation in Waiapu County (it should be noted that this is not the same physical boundary as the Waiapu catchment) revealed that over 95% of the county was in LUC class 6 (16%), 7 (67%), or 8 (13%) land. The steep slopes and soil erosion problems, due to the lithology and high rainfall of the region, have made farming a difficult proposition. While forestry was also difficult, due to expensive roading and harvesting costs on such terrains, it was still seen as a useful alternative to pastoral agriculture because it provided soil protection as well as diversity of employment. They identified the Waiapu region as typically under-developed, with high unemployment, especially for women, and high occupancy of houses but with strong community values, sustained by the notion of self sufficiency (Bray and Kinge, 1984).

Similarly Aldwell (1984) explored some social and economic implications of large scale forestry in the Waiapu County. Time series data on population, employment, and services were used to examine changes that occurred between the periods 1961 to 1981. These periods were chosen because of extensive afforestation in the late 1960's to reduce erosion on pastoral hill country. Results showed that the indirect effects of forest sector growth were reduced because of the historically depressed state of the region. Forestry reduced the rate of rural decline rather than providing a boost to the local economy. Despite these results, the forest sector did employ 10% of the local workforce and population growth was also recorded (Aldwell, 1984). Thus, future problems were not expected to be related to de-population but in meeting the demands of a growing population through employment, for example, and a forest-based service sector.

A review by Jones et al. (2008) on the economic costs of hill country soil erosion and the benefits of its control in New Zealand found that it was an under-studied area and some of the component costs associated with hill country erosion are inherently difficult to disaggregate, quantify, and assess particularly as erosion impacts have both on- and off-site implications. Blaschke et al. (2008) also concluded in a review, that New Zealand regional and national estimates of soil erosion costs and the monetary value of soil conservation benefits are imprecise as they are based on limited data and are not particularly useful for estimating cost-benefits of afforestation practices to reduce erosion. Harmsworth et al. (2002) emphasises that for the benefits of erosion control to be effective, it is essential to develop environmental enhancement alongside economic development and human and social capacity building.

The East Coast Forestry Project (ECFP) was introduced with the aim of afforesting to control soil erosion, provide employment and regional development, and recognise individual environmental property needs. A study into the indirect and induced employment effects, such as reduced employment in agriculture or a greater need for services causing spin-off employment, were looked at using an input-output table for the Gisborne region over a 28 year period (Butcher Partners Ltd., 1995). The report suggested that an estimated afforestation of 4,000 ha/yr would result in an initial rapid increase in net employment which begins to level out from year 10 due to a continuous decline in agricultural employment as further land is converted to forestry. It should be noted that much more data on forestry was collected than for agriculture and thus estimates may be biased towards forestry. Nevertheless, at the end of the first forest rotation there was a small increase in net employment in the region, which could have been greater if more processing occurred within the region.

Tomlinson et al. (2000) explains that while the ECFP has been considered environmentally effective, many with rural interests question whether the ECFP encouraged people to plant sustainable farming land. An East Coast resident commented:

> *"One of the reasons that the farmers sold out here, and they managed to get so many trees in, was that the government was offering tax rebates to the forestry companies. It wasn't offering tax rebates to other farmers, so that when the farm went on the market they got offered a fortune for it. I have family members who sold the farm for double its value as a sheep and cattle farm to the forestry..."* (p 21).

Tomlinson et al. (2000) found anecdotal evidence that some people from the rural areas of the East Coast challenged whether much of the land converted to forestry is the best economic use for that land. This embraces the argument that farming land provided continual short term returns and supported longer-term employment opportunities. However, it could now be argued that most arrangements around carbon forestry offer an annuity for landowners instead of or as well as a stumpage (T. Porou, pers. comm.). As previously mentioned, forestry has been seen as taking over ‗good' farmland. A quote from an East Coast based business interest without forestry connection relays concerns the following:

> *"The major thing is that trees don't produce an annual income. The farmer used to have an income each year. It was also locally owned in most cases. There are places up here that used to support five families. Plus, all the shearers and other workers that came in. Now there is a locked gate there. It doesn't support anybody. They come in and prune it after five years. Someone from outside the district usually. Then they will prune it again and eventually they will log it. Between these times there is no money coming out of it all. I don't know who actually owns that, but it won't be anyone local. When it is eventually felled the money won't come here it will go somewhere else."* (p 20).

The key policies that have been put into practice to reduce erosion in the East Coast region are noted in Appendix 5 with the definition and purpose of the policies summarised. Rhodes (2001) provides a broad description of the evolution of the forestry policies in place on the East Coast to reduce the effects of erosion. He emphasises how the region is still suffering from the anthropogenic and natural effects of erosion in the past. Increasing forestry in the region has improved employment overall in the region, as noted in the above literature, but this is often in townships and at the expense of rural farming communities. However, there are net regional gains from forestry in the form of increased employment and greater soil conservation, overall. Giera et al. (2007) emphasises that understanding the local communities and farmers, and the social, economic, and political context that landowners operate within, is of importance for developing successful initiatives and for those implementing policy.

3.2.2.1 The nature of employment

Employment in the Waiapu catchment has largely been land-based work consisting of work in stock farming, fencing, and farm-related work, scrub cutting, forestry, vineyards, horticulture and road-works (Harmsworth et al., 2002). More recently, exotic forestry has generated employment (including planting, pruning, logging, and truck driving) (Harmsworth et al., 2002).

Much of the land-based work in exotic forestry is contracted and Tomlinson et al. (2000), found that the local people believe that many of these roles are taken by contractors both from inside and outside the region, with the latter hiring outside people or local people on short-term contracts. Exact figures are not available on the number of contractors in the region, especially for silviculture contractors due to the nature of the work which is short term (Tomlinson et al., 2000). The boom bust nature of this contracted work is referred to by Tomlinson et al. (2000) in the following terms:

> *"There is plenty of forestry work, it is just securing it. There are a lot of other people that will show up, think they can do it for cheaper. That pushes you out of the way, when you are a serious contractor. They'll get in there go like a bat out of hell. Then go broke. What's the point in that? The guys that work for him get less money. He goes broke. There are a whole lot of workers looking for another job, and the forestry company wins there because they got the job done cheap. That is not really helping the communities."* (p 29).

Tomlinson et al. (2001) described that the nature of contracting has resulted in many of the contractors to be regarded as unscrupulous through under-paying and not paying workers, disregarding the safety and welfare of workers, and paying workers in drugs. They also describe that Work and Income New Zealand representatives attribute the reputation of forestry contractors as the main reason why people are not remaining in forestry work. The nature of the work is quoted by commentator as follows:

"Silviculture is the bottom rung of forestry work. The forestry companies offer a price, the contractors do what they can to try and pay the wages." (p 31).

There are tensions amongst workers, if you hire a lot of workers especially. I am selective about who I hire because I don't want bad feelings from workers. If they have got a big family and the nagging wife who wants lots of money, you'll find as a contractor that you will cop it more from those workers, because they really need the money. They can't miss a day. Bad weather. Hail. Rain. Snow. They have to work else their house might get taken off them or they can't afford the rent. There is just not enough money there for the people like that. I am careful to try not to hire those people because it is not worth the stress. With the workers I have got, I try to ensure that they are the best I can get, and keep them happy." (p 31).

Moreover, a contracted forestry worker can be described as a rare breed as the nature of the work affects who can and will participate (Tomlinson et al., 2000). For example, following is a paraphrased account of a day's work as told by an ex-silviculture worker from Tomlinson et al., 2000):

"A forest worker is a special breed of man. A certain hardness, drive and heart is required. For many of the men the job involves getting picked up at four AM with a two hour drive into the forest (where you sleep), a full physical days work in the forest, with two half-hour breaks (if you want). You finish late in the day, have a two hour trip home (where you sleep). You go home make your sandwiches for the next day and you "crash" to sleep until you wake for the next day's work. Many men do this six or seven days a week. Men go into the forest in stinking heat and freezing rain. There is a mental hardness associated with being in the forests." (p 45).

The demanding and potentially dangerous nature of contracted forestry work, particularly the silviculture work, results in few who would accept the work or stay in it for a length of time, despite high levels of unemployment in the region (Tomlinson et al., 2000). Moreover, the nature of contracted employment results in elements of distrust and a lack of stability in the forestry workforce (Tomlinson et al., 2000). There are positive comments regarding the nature of the work around physical fitness, working outside, and that with the right mental and physical ability, a person can earn a reasonable income (Tomlinson et al., 2000). To help this view, the current conditions for workers and contractors are expected to improve, based on the anecdotal evidence discussed by Tomlinson et al. (2000), as the demand for skilled and well organised crews increases.

3.2.2.2 Security & quality of employment for forest workers

Forestry generated employment for people in the Waiapu catchment is largely contracted work to forestry companies. Tomlinson et al. (2000) described a tension that exists between workers and employers in the forestry sector region, which according to the workers themselves has arisen due to a deliberate distance established by the companies. They further described that many workers see that contracting ensures that the worker has no direct relationship and they feel alienated from the company for whom they are actually working. Tomlinson et al. (2000) acknowledged that companies did have some input in the people that work for them through set targets for qualifications, health and safety procedures, and they encourage the development of management in the contractors. They further discuss that companies do recognise that there are issues in the labour force and without willing and capable workers; the silviculture capability could be lost. However, the forest companies continue to offer low contract rates for the work to be undertaken and therefore low rates for the forest workers and their families, which is recognised in the community (Tomlinson et al., 2000). A quote captured by Tomlinson et al. (2000) describes an ex-contractor who feels that financial reward paid for the work is inappropriate:

> *"Would you want to work for $100 a day… performing at that degree? When you could make $100 a day sitting in a chair fiddling with a pen. These guys have to perform to that degree for just an average pay. They are not average men. It is time that forestry realised that and paid them for what they are."* (p 32).

In Tomlinson's view, the nature of forestry work has resulted in contractors finding it increasingly hard to find skilled and ‗good' quality workers, moreover, to maintain work health and safety and motivated crews (Tomlinson et al., 2000).

3.2.3 Te Reo & tikanga

Language holds the key to the past. Harmsworth et al. (2002) describe that the long history of a dominant traditional Māori culture in the Waiapu catchment is evident in the many significant cultural sites and place names that tell the stories of activities, features, important events, and important people. They described that these place names are pivotal expressions for both the past and fundamental for forming and understanding aspirations for the future and provided a detailed account of the meanings and origins of place names within catchment.

The meaning of Tikanga is recorded by Harmsworth et al. (2002) as the lore, made up of custom, rules, regulations, and protocols to make sense of the world, determine responsibilities and relationships between people, and regulate the use of natural resources. Tikanga provides a set of principles and practices to achieve the goal of mauri maintenance (Harmsworth et al., 2002). These principles are summarised in Harmsworth et al. (2002) and recognise four planes of reality that give balance in an environmental system and together help Māori understand the natural environment:

- taha tinana – a material state, the body,
- taha hinengaro – a mental state,
- taha wairua – a spiritual state,
- taha whanaugatanga – a related or associative state.

These principles held by Māori are also fundamental for forming and understanding aspirations for the future.

3.2.4 Whanau

The land use change in the Waiapu catchment has had considerable impacts particularly on rural communities. The present perception is that conversion of farmland into forestry has resulted in once booming rural communities to become socially dislocated and ghost towns (Tomlinson et al., 2000). Tomlinson et al. (2000) quotes some East Coast farmers talking about the impact of forestry on farming communities:

> *"They have buggered the social structure so much up in the areas, that they are not having any social life whatsoever. They will sell those places. They are all scared of being the last man in the valley, or the last ones to turn the lights off. There will be more people having to sell up because of the lifestyle that is being forced upon them."* (p 19).
>
> *"Lots of families up and down the East Coast have sold and gone. The social fabric has disappeared completely."* (p 19).

A comment from a Gisborne resident was typical:

> *"I don't think you are going to see a terrible lot of farming left in the future. It is like a terrible ball that is rolling. The reason for that is…the farmers are saying they have lost the infrastructure. They have lost their community.*

They have lost their days out of golf. They have lost all the family get-togethers. They are quite lonely and don't want to be the last one to shut the door, so they want out and they are getting out. We have some very influential farmers around now who are saying they have had enough. They are getting out. They don't want their kids travelling to school every day with that amount of logging trucks on the roads. They don't want to be part of it. It has got to the stage where people out the back here were the only ones left. They were surrounded by trees. They were dead scared that they would catch fire (laughs). They had no option but to sell up and buy a farm in Hawkes Bay. They just couldn't stay there." (Tomlinson et al., 2000, p 19).

The impact of plantation forest land use in the community, particularly the nature of the work and rates of pay have a direct impact on the families. The impacts felt through the community are summarised by a quote from a woman out of Tomlinson et al. (2000):

"The impact of the low pay affects the families of workers. It affects the women and relationships through stress factors." (p 33).

"A male may work in the forest, yet that does not guarantee a minimum wage. The woman is put in a situation when buying food and basic essentials where she can't and this creates stress…" (p 33).

However, Tomlinson et al. (2000) did find some evidence of perhaps an emerging succession of forestry work amongst whanau. For example:

"I imagine you would be looking at the guys pruning and planting. I imagine that employment group is predominately Māori. In part it is due to where the forestry is occurring, like up the Coast. Like I said some of the training programmes focus on Māori. I would also imagine that that sets up a culture. Forestry is something that people in the whanau are doing. Therefore, there is a greater chance the other people will move into it because another family member is doing it." (p 56).

The perceptions of rural community decline were demonstrated using more quantitative techniques by Fairweather et al. (2000). They described the rural community decline as valid but commented that the relationship between forestry and agriculture is not as simple as some commentators suggest. They conclude that a shift from pastoral farming to forestry appears likely to accentuate rural job losses and other associated changes in community profile, but cannot be blamed for the entire decline. Moreover, they consider that the development of forestry is generating economic activity within the region. However, the benefits of that activity are not distributed evenly to all communities.

3.2.5 Mana motuhake

Harmsworth and Warmenhoven (2002) consider that there is a deeply felt pain at the state of the environment and that the closely held spiritual connections to land, water, and people will drive aspirations which include: future roles, vision, goals, relationships, issues, and direction. One example, they quote, that was repeated by many of their interviewees in their study explained that:

> *"Whanau/hapu have a right to manage and a responsibility to sustain ecosystems within their geographical boundaries."* (p 7).

Harmsworth and Warmenhoven (2002) argue that, based on such a deeply held notion, it will follow that hapu and whanau will logically seek mana motuhake/manawhenua over the river and catchment – and its restoration or healing. This is supported by an agreement that the catchment needs a strategy to change to represent the aspirations and values of the community
(Harmsworth et al., 2002).

Experiences of Ngāti Porou feeling depowered with land use ventures can be shown by Harmsworth et al. (2002) who comments on a past experience with growing grapes in the Tikitiki community. They describe that during the 1970's Maori Affairs and Penfolds wines petitioned Waiapu landowners to develop vineyards on their land with a total of 200 ha of land invested and considered to be a lucrative enterprise by landowners. However, during the 1980's the grapes were poisoned as a result of a government directive. This has resulted in the community around Tikitiki to practice extreme caution when entering horticultural or government-initiated land development schemes. Harmsworth et al. (2002) captures a landowner/investor's comments:

> *"During that time that we had the grapes in we were able to work. All the landowners were working…You know, we could have had a winery set up here, someone could have given a bit of land to put the winery on and we could have made our own wine here. Two hundred hectares of land all went into grapes… And each block had a different variety." (p 51).*
>
> *"They didn't even tell us why they poisoned the grapes, and I said to them, "Well, open the paddocks and let the people help themselves." They*

wouldn't even do that, they locked the paddocks and they poisoned them. It was unbelievable…gosh, we cried, it was just sad. When that happened, you should have seen…the people went into a rut, they went into a real rut…there was no money coming in. That was a sad time for us." (p 51).

Moreover, Tomlinson et al. (2000) highlighted that plantation forestry land use has brought forward the feeling of being insignificant to corporate forestry. They highlight the lack of local wood processing and comment that the public resent seeing increasing numbers of logs being exported. They also described how the role of the government in deciding a policy regarding the future of forestry on the East Coast is felt to have contributed to a sense of ―exploitation". They supported this assertion with the following quotation:

"The National government wiped the East Coast. They didn't know what to do with it. So they drew a line and said „plant trees in that area'. And that is what happened. There was no thought of what did actually bring more money…" (p 36).

Tomlinson et al. (2000) described that there is a belief that larger forest companies in the region, particularly those with international ownership, have no real interest in the community's welfare. They quote the following examples of community feelings about forestry company's commitment to the region:

"The forestry companies put nothing back into the community as a company… The only people making it are the forestry companies. It is slightly raping the people. Taking everything from the people. And, when they've had enough. They'll leave them with their desolate land." (p 36).

"Part of the thing is that they don't have ownership within the community, so it doesn't really mean anything to them. It easier to come in, do your thing and walk out. It is up to the people living in the communities to pick up the pieces. It would be nice to think that [forestry companies] would take on a social policy, but they won't. Being in forestry is to make money. It's not to make friends." (p 37).

Tomlinson et al. (2000) acknowledges that the community has a desire to become more involved in the decision making process regarding the future of forestry in the region. However, there is still some development to be done to include the community voice. Tomlinson et al. (2000) illustrate this point with the following comments from community workers in the Gisborne East Coast Region:

"Whenever there has been a conference on forestry, a taskforce or a meeting, the only people that are going to turn up are the forestry companies. If it concerns forestry encroachment onto farming land then you'll get all the farmers there. But where are the forestry contractors and forestry employees? Have they thought to be involved in the consultation process as well? All you are hearing from is the top management. I'm thinking the whole community should be involved in this thing as well." (p 37).

"I would like to see that there is more discussion in terms of what can we, in partnership with you, not just for the money, but as a community, what can we do that is actually going to help us all grow. Financially. With Jobs. With quality of life… Building the capacity of the community. That is what it is about. Then we all could come out as winners. Or, we feel like we are winners." (p 37).

Tomlinson et al. (2000) quotes an example of an appeal for more integration in policy development which reflects, to some extent, Harmsworth and Warmenhoven (2002) in their consideration that social and environmental issues cannot be separated for Ngāti Porou.

"The government needs to start saying that it will start looking at the economic development and the social development together. This region needs a full needs analysis. Start at the bottom and work up. We have had too much throwing money at the Māori and fix up the problem. It does not fix up the problem. If you work on the social issues, people will start coming together and building the economic solutions. As long as we keep fragmenting and throwing money here and throwing money there, with the social workers and other organisation freaking out because money is being thrown in the wrong direction. Nothing is going to change." (Tomlinson et al., 2000, p 37).

Harmsworth et al. (2002) discussed how Ngāti Porou want to see more productive use of the land and sustainable land use diversification utilising cultural knowledge and resources, including better access to mainstream science and technology. They also argued that the development of any type of planning must consider the community's social, cultural, and economic sustainability as well as the environmental sustainability with local government and science agencies working in collaboration with the Waiapu community.

3.2.6 Connectedness

A decline in social cohesion in the region is discussed by Tomlinson et al. (2000). They comment that the decline is not specific to Ngāti Porou or the Waiapu catchment but may represent a typical picture for rural communities. The social cohesion has changed possibly due to the make-up of the people within the community which has changed (Tomlinson et al., 2000). Tomlinson et al. (2000) gives an example of the disappearing voluntary sector where the change is being noticed.

The East Coast has extensive social networks. Tomlinson et al. (2000) quotes a person with close community work connections to the Coast:

> *"There are not a lot of people up the Coast doing nothing even if they are not employed. There are a lot doing voluntary work, especially on the Coast. It is very hard to find an unemployed person at home, because they run the infrastructure of a lot of things up there. The schools. Things to do with older people. They don't have the organisation there to help them. So, they have to help themselves. If you actually start forcing people to go to work these other infrastructures will fall down."* (p 18).

Tomlinson et al. (2000) explains that the forest sector development is not directly linked by people to these trends. However, there is a loose association in peoples' minds that the two are somehow linked.

3.2.7 Matauranga

There are five main types of traditional knowledge all with a strong cultural base providing a Ngāti Porou cultural perspective on the environment, and a holistic Māori world view which is unique to the Gisborne–East Coast and Waiapu area (Ngāti Porou, 2002; Warmenhoven, 2002 in Harmsworth & Warmenhoven, 2002). The main knowledge forms defined were summarised by Harmsworth and Warmenhoven (2002) (p 5):

- *Contemporary knowledge (e.g. modern view of the world),*
- *Historical knowledge (e.g. historical accounts of floods, changing land use, etc.),*
- *Local knowledge (e.g. local farmer knowledge, fishing knowledge),*
- *Aspirations (e.g. aspirations drawn from traditional and a modern world view and experience),*
- *Matauranga or traditional Māori knowledge including values (e.g. traditional values, te reo, customs, practices, puuraakau (narratives, stories, myths), traditional environmental knowledge).*

Harmsworth and Warmenhoven (2002) describe Matauranga below:

> *"Matauranga separated from the other knowledge forms and given special status, was defined as traditional and special knowledge handed down through ancestors, tohunga, tipuna, kaumatua, and other elders, usually people with specialist skills requiring in-depth cultural understanding and practice. While some forms of matauranga are sacred or specialised and practised by very few Māori in contemporary Māori society, other examples have become general knowledge in books, papers, and manuscripts. Matauranga includes knowledge of the world and is equated with wisdom, several specialist forms include: ancestry (whakapapa), values (tikanga), language (te reo), medicine, health and wellbeing (rongoa, hauora, oranga, whaiora) weaving (raranga), carving (whakairo), matariki (seasonal planning), maara (cultivation, food production) environmental management and biodiversity (kaitiakitanga), agriculture and fishing (ahuwhenua, mahinga kai, hi ika, maangoingoi, rapu tuna, kaimoana), tattoo (moko), songs (waiata), moteatea (chants depicting significant historical statements), prayer (karakia), proverbs and quotations (whakatauaki, pepeha). The Waiapu project has recorded only matauranga special to those hapu collectively known as Ngāti Porou, with relevance to traditional practices, Ngāti Porou values, and the history of the Waiapu catchment". (p 5).*

> *"Ngāti Porou values (part of matauranga) were drawn primarily from the thoughts, knowledge, experiences and feelings of the pakeke (adults) and kaumatua (elders)". (p 6).*

Based on the extensive research of Harmsworth & Warmenhoven (2002), the following table (Table 3.1) identifies a range of issues arising from recorded Ngāti Porou sources which integrates knowledge of tangata whenua with information needs that will aid the development and description of a desired state for the Waiapu catchment.

Table 3.1. The contribution of matauranga to mainstream science (Harmsworth & Warmenhoven, 2002, p 6).

Māori knowledge	Provides information and helps to understand and plan
Place names and explanations and stories associated with each	Catchment history, change, land features and associated Māori history, mythology. Names are often linked to a historical record of events, habitat condition, activities, and people Baseline record of condition of rivers, streams, land, habitats, rocks, river course
Māori values particularly relating to the environment, spiritual beliefs, Māori wellbeing, social and political ideals	Issues, values which underpin environmental management, environmental standards, future goals, aspirations and policy
A land-use history from a Māori perspective	Environmental change and impacts on people's lives. Experience that affects present behaviour, perceptions, views, aspirations
A record of floods and storms and related stories	Environmental change and impacts on people's lives. Experience that affects present behaviour, perceptions, views, aspirations
Concepts of health and ecosystems	Definitions of health and ecosystem, environmental standards, indicators, perceptions of environmental condition and quality
Traditional sites, cultural heritage, culturally significant places, wahi tapu (sacred sites), papa kainga	Geographic location, cultural value and significance of certain sites, places, uses, purposes, activities, for future planning and policy, appropriate land use, priorities, management, restoration
Values, kawa	Community organisation, responsibilities, relationships, co-learning, collaboration
Cultural practice, customary use of resources, kai (food, harvest, fishing, hunting, weaving), location and type of customary use	Spatial and temporal record of catchment, change in condition, quality, and area of habitats, degradation, environmental change, rate of change
Rongoa (Māori medicines and practice)	Spatial and temporal record of native forest habitats, wetlands, plant communities, ecological change, restoration strategies
Fishing and Hunting (record of the past)	Resource depletion, quality, change in environmental condition, degradation, habitat restoration strategies
Native bird populations and habitats (record of the past)	Resource depletion, quality, change in environmental condition, degradation, habitat restoration strategies, aspirations
Taonga, flora and fauna resources, plants, animals, fish, native birds	Loss of flora and fauna, temporal and spatial record of habitats, change, restoration strategies, aspirations
Water classifications	Water quality and quantity, condition of river and streams, groundwater, change in condition, quantity and quality of springs
Cultivation, mahinga kai	Resource condition, value, environmental change, resource use, activity, indicators, future sustainable resource planning

3.2.8 Clean environment

Tomlinson et al. (2000) describes how opinions expressed on the environmental impact of forestry were limited in his study. They state that people talk of the impact of Cyclone Bola in 1988 and feel that the ECFP has gone a long way in preventing similar damage in the future:

"I am pleased to see the change in land use on the hills, as the whole area is prone to erosion. There is a greater stability than there once was, and it is the forests that are making that difference. A lot of the steeper hill country should never have been cleared. So, it is good that it is going back into trees. I notice that once they mill them they replant within the year, making the land more stable." (p 23).

Tomlinson et al. (2000) does mention that biodiversity is another environmental concern but refers more to biosecurity incursions rather than loss of native or indigenous biodiversity. Views on the impact of forestry on native plants and wildlife were also expressed. Plantation forests are regarded as the source of many weed species and pests. Warmenhoven (2004) quotes a Ruatoria resident as saying:

"Yes, forestry is a shocker. Once the trees go in the forest owners do very little about any type of weeds, and it's not just plant pest bit also animal pests, goats and pigs, which play havoc with fences and pastures." (p 9).

3.2.9 Infrastructure

Infrastructure development in the Waiapu catchment and East Coast face a number of major issues, for example; the quality of the roads, alternative transport, and secondary port options (Tomlinson et al., 2000). Tomlinson et al. (2000) quoted an East Coast non-forestry owner as follows:

"When considering [The East Coast] hasn't got the electricity supply ready yet though they are working towards that. They haven't got the roading infrastructure in place able to handle it. They haven't got the port infrastructure in place able to handle it. I doubt they even have the water supply. It could certainly be set up in Gisborne. But if you want a major development in Ruatoria, you've got… problems." (p 9).

There are fears by the community of losing the physical infrastructure due to flooding and sedimentation in lowland areas (Harmsworth et al., 2002).

3.2.9.1 Wood processing

With a change in land use to plantation forestry, Tomlinson et al. (2000) highlighted a perceived need at the time for additional processing facilities with a belief that the volume of trees to come on stream would dictate the need for other processing and therefore jobs on the East Coast. However, they also commented that other community members signalled low confidence. Tomlinson et al. (2000) quotes a view from a non-forestry community observer who represented a common view about the future of processing:

"The forestry industry has basically been set up for log export. The dream of setting up value-added industry in the region is unrealistic and unlikely." (p 10).

3.2.9.2 Roads

The biggest infrastructure concern in the East Coast region is the roads with the largest concerns, reported by Tomlinson et al. (2000), to be the increase in logging traffic combined with poor quality roads. They comment that an often quoted statistic by council representatives and community members is ‗that there is currently a logging truck on East Coast roads every five minutes and predictions are that this will increase to a logging truck every one minute'. They also comment that some observers doubt the ability to upgrade the roads to the ‗required' standard, for example, an East Coast farmer stated:

"There are huge problems as the stream of logs come on board. For the very same reason the land is unstable for farming, it is unstable for roading. To get the road up to a standard to cope with the increase in logging trucks and the rest of the traffic. It is going to be a nightmare for whoever does it." (p 12).

The increasing numbers of logging trucks are seen as detrimental to the region's roads contributing to congestion, the slowing of traffic flow, road damage and wear-and-tear on vehicles (Tomlinson et al., 2000; P. Pohatu, pers. comm.).

3.2.9.3 Alternative transport & port facilities

Tomlinson et al. (2000) noted the importance of the port in Gisborne to the whole region. However, they also noted consideration at the time of a second port to be built further up the East Coast – the suggestions being Hick's Bay, Tolaga Bay, and Tokomaru Bay.

Various transport alternatives have been suggested in response to the roading and port capacity concerns with the two most public options being barging and rail (Tomlinson et al., 2000). A Tokomaru Bay resident explains:

"It was always thought that there would be a port at Hicks Bay or barging operations at smaller bays up the Coast. That still has to be an option. There is talk of another port at Tolaga Bay. That seems incredible. I can't see that they can maintain a port in Tolaga and Gisborne. I would have thought that there would be more sense in railing." (Tomlinson et al., 2000, p 14).

3.3 Summary & conclusions

- The Waiapu catchment is of great spiritual, cultural, and economic significance to Ngāti Porou and the health of the catchment extends much further than the physical elements of the landscape:
  - *"The health of our river depends on the hapu that inhabit those valleys that fed into the Waiapu. And if their health is not good, neither is the health of our river."* (Harmsworth et al., 2002 p28).
  - *"Kai (food) that we put into our mouths, our hinengaro and our wairua - you have to feed all three. They must all be healthy…. Health is nurturing or feeding these things."* (Harmsworth et al., 2002 p28).
  - *"The whenua, including all waterways, is Papatuanuku, the nourishing provider, and the protector of all living things. Together with Ranginui, the air we breathe, she allows us to use and exploit elements of her that are necessary for our survival. Through life we remain her dependent offspring and in death we return to her."* (Harmsworth et al., 2002, p28).
  - *"The river is our taonga and our life essence."* (Harmsworth et al., 2002, p28).
- Many Ngāti Porou have had concerns about commercial forestry as a means to control erosion:
  - *"Pine forests will cause a lot more erosion. Cause run-off waste. They don't fall like natives. If forests were growing with natives it would be all right."* (Langer and Tomlinson, 2003, p19).
  - *"[Pine forests] destroys our precious and sacred land. Then when they grow and are being felled, the land looks bare and raped."* (Langer and Tomlinson, 2003, p19).
  - *"Takes too long to reap benefits. By the time our mokopuna come along there will be pine all around and not everyone will be able to work it. Also pollutes the land. The place for forestry is where slips and erosion are. Not on good farmland. The chemicals are going into our rivers, polluting our water, killing our wildlife – farmers too."* (Langer and Tomlinson, 2003, p19).
  - *"No more good land should be taken up in forestry. Usurping the mana. Land is mana to Māori. Should have a certain level that forestry develops to unless there is 100% gain for Ngāti Porou. Too many men from outside."* (Langer and Tomlinson, 2003, p28).
- The disestablishment of the New Zealand Forest Service and subsequent sell off of forests had major impacts on Ngāti Porou communities and their view of Governmental agencies:

- *"When the forestry came in there were great hopes with the government run forestry scheme, right up to 1983. Then the Labour government decided to sell the forests. That was a major error in my opinion, as far as employment. A lot of Māori had come back here and they came back from the cities, they'd taken out a mortgage and basically they had lost everything. They built a home and suddenly there was no work."* (Tomlinson et al., 2000, p54).

- Concerns that families and communities have become socially dislocated:
  - *"They have buggered the social structure so much up in the areas, that they are not having any social life whatsoever. They will sell those places. They are all scared of being the last man in the valley, or the last ones to turn the lights off. There will be more people having to sell up because of the lifestyle that is being forced upon them."* (Tomlinson et al., 2000, p19).
  - *"Lots of families up and down the East Coast have sold and gone. The social fabric has disappeared completely."* (Tomlinson et al., 2000, p19).
- Many Ngāti Porou seek mana motuhake over the river and catchment – and its restoration or healing. This is supported by a view that the catchment needs a strategy that fully represents the aspirations and values of the community (Harmsworth et al., 2002).

3.4 Knowledge gaps & recommendations

Based on the review of relevant literature and the feedback from the consultation undertaken as part of this study, the following were identified as knowledge gaps and areas for future research. These are listed in order of priority:

1. There is no integrated and overarching strategic plan for the catchment that describes how the aspirations of Ngāti Porou, as described in this report, maybe achieved. The development of a plan that describes plausible scenarios for the future co-developed by all stakeholders will aid the community and decision makers in their deliberations on likely options and choices. Any strategic plan should be supported by the development of a co-governance body that includes all relevant agencies and community representatives. Further research is required on the best and most appropriate co-governance model appropriate to the needs of the catchment and the community.
2. An evaluation of the impact of erosion and land degradation on the livelihoods of Nāgti Porou should be undertaken. The Waiapu community may be viewed as possessing financial capital, social capital, human capital, physical capital, and environmental capital. Erosion and subsequent land degradation has reduced

these capitals in many direct and indirect ways and thereby reduced the ability of the community to sustain itself. A better understanding of the impacts of erosion on local people will help inform the development of policy and guide the community's own responses to the challenges they face in a more targeted and effective way. To be a resilient community able to withstand future natural, political, or financial shocks, the level of all of these forms of capital must be raised. To be in a position to take the necessary long-term view when planning land usage — this similarly requires a solid and resilient base. People living week to week cannot be expected to overlook pressing need and make investments with a return 20-100 years away. An aspirational set of measurables based on these forms of capital is essential not only as a source of specific developmental targets, but also as a way to gauge progress both internally and in relation to the country as a whole. To repopulate and thrive, the catchment has to not only recover, but has also to compete favourably as a place to locate a family when weighed against alternatives such as Gisborne or Wellington.

3. Land use optimisation and local community economic development should be investigated. Using the livelihoods approach described above, a series of land use options should be developed and supported by a detailed understanding of the capital held within the community. This understanding will help to guide an evaluation of the likely success of each option and highlight obstacles to implementation such as training needs and lack of access to financial capital.
4. Quantification of the ecosystem and environmental services provided by the Waiapu and its tributaries to Ngāti Porou including kapata kai should be undertaken. Using non-market valuation techniques to survey local people together with econometric analysis, the social and cultural values of the ecosystem services to the local people in the catchment may be estimated. In addition, the reduced ecosystem function associated with erosion could also be quantified, for example, the loss of kapata kai, fish, and plant resources. The result would be an estimation of the economic impact of erosion on a community and region.
5. An evaluation of the impacts of erosion on archaeological and wahi tapu sites within the catchment needs to be addressed. Important sites should be identified and safeguarded from further damage and loss. Consideration should be given to the restoration of damaged sites and active management plans put in place.
6. The Ngāti Porou aspirations and supporting indicators require further consultation and refinement with the wider community. Indicator processes are not static and require iteration and development over time as priorities emerge and the desires of the community are better articulated.

7. Effective community engagement processes towards improving the health of Waiapu catchment and in erosion and catchment management through greater scientific awareness and improved technology transfer between interested parties, including CRI's, GDC, Ngāti Porou, and other landowners are required.

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4 Benchmarking, scope assessment, & critical evaluation – geophysical aspects

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4.1 Introduction

To provide a baseline from which to assess the size and scale of the erosion problem going forward, the present (2008) state of the catchment has been described, utilising information gained from the literature review of the geophysical aspects of the erosion problem, together with geospatial datasets. Three other dates (1840, 1969, and 1988) were chosen to describe past catchment states, to enable assessment of the impacts of past land use changes and storm events, and the effectiveness of past efforts and policies to address the erosion problem. The 1840 date was chosen to represent catchment conditions prior to large scale deforestation which began in the 1880-1890s, and which also represents conditions under Māori settlement. A vegetation map of the catchment as at 1840 was compiled by Harmsworth et al. (2002). The 1969 date was chosen to represent conditions prior to the commencement of afforestation efforts. The 1988 date was chosen because Cyclone Bola, which occurred in March of that year, had a major impact on erosion and sediment flux in the catchment. Where information was available, conditions have been described both pre- and post-Bola. Where available, a geospatial description of vegetation/land use, erosion, and river conditions was made for these four points in time. An assessment of the size and the scale of the erosion problem in the catchment is given and uncertainties associated with climate variability, large storm events, climate change, and earthquakes are discussed. A critical evaluation of past and current erosion mitigation measures is presented.

4.2 Methodology

Data on the distribution of vegetation was obtained from the following sources for each benchmarking date (Table 4.1).

Table 4.1. Sources of vegetation data.

Benchmarking Date	Vegetation data source
1840	Historic vegetation map from Harmsworth et al. (2002).
1969	Vegetation and land cover information was derived from NZMS 260 Topo series vegetation GIS layers, (mapped from aerial photographs taken from 1973-1976). Forest plantings were subtracted from this layer to represent conditions prior to afforestation.
1988	Vegetation was obtained from 1990 LUCAS mapping (http://www.mfe.govt.nz/issues/climate/lucas/).
2008	Vegetation was obtained from 2008 LUCAS mapping (http://www.mfe.govt.nz/issues/climate/lucas/).

Data on the area and distribution of gullies, and suspended sediment yield estimates at 1969, 1988, and 2008 were supplied by Landcare Research. See Herzig et al. (2011) for a discussion of the gully modelling methodology.

Information on river cross sections (aggradation rate, mbl, and channel width) was supplied by the Gisborne District Council (GDC) and analysed by Dave Peacock (Peacock, 2011). Additional information was obtained from Paine (2009).

4.3 Catchment conditions at 1840

4.3.1 Vegetation

A vegetation map c. 1840 has been compiled using existing vegetation and historical information (Wards, 1976; McGlone, 1983; McGlone, 1989; McGlone et al., 1994; Department of Survey and Land Information, 1995), GIS classification and inference, district planning records, and local Ngāti Porou knowledge records, and historic photographs (Harmsworth et al., 2002) (Figure. 4.1). Table 4.2 lists the vegetation types and their areas.

Table 4.2. Vegetation in the Waiapu catchment c. 1840 (from Harmsworth et al., (2002).

Vegetation type	Area (ha)	% of Waiapu catchment
Podocarp forest	3,465	2.0
Lowland podocarp-broadleaved forest	71,905	41.5
Podocarp-broadleaved-beech forest	56,548	32.6
Lowland beech forest	16,166	9.3
Highland beech forest	4,236	2.4
Scrubby forest and scrub with scattered fern	13,439	7.7
Manuka, kanuka/Podocarp forest	534	0.3
Manuka, kanuka	6,085	3.5
Subalpine scrub	1,013	0.6
Sand dune vegetation	21	0.1
Total	**173,412†**	**100**

† Note that the total catchment area as given in Harmsworth et al. (2002) differs slightly from the total catchment area calculated by GIS analysis in the present study (173, 815 ha).

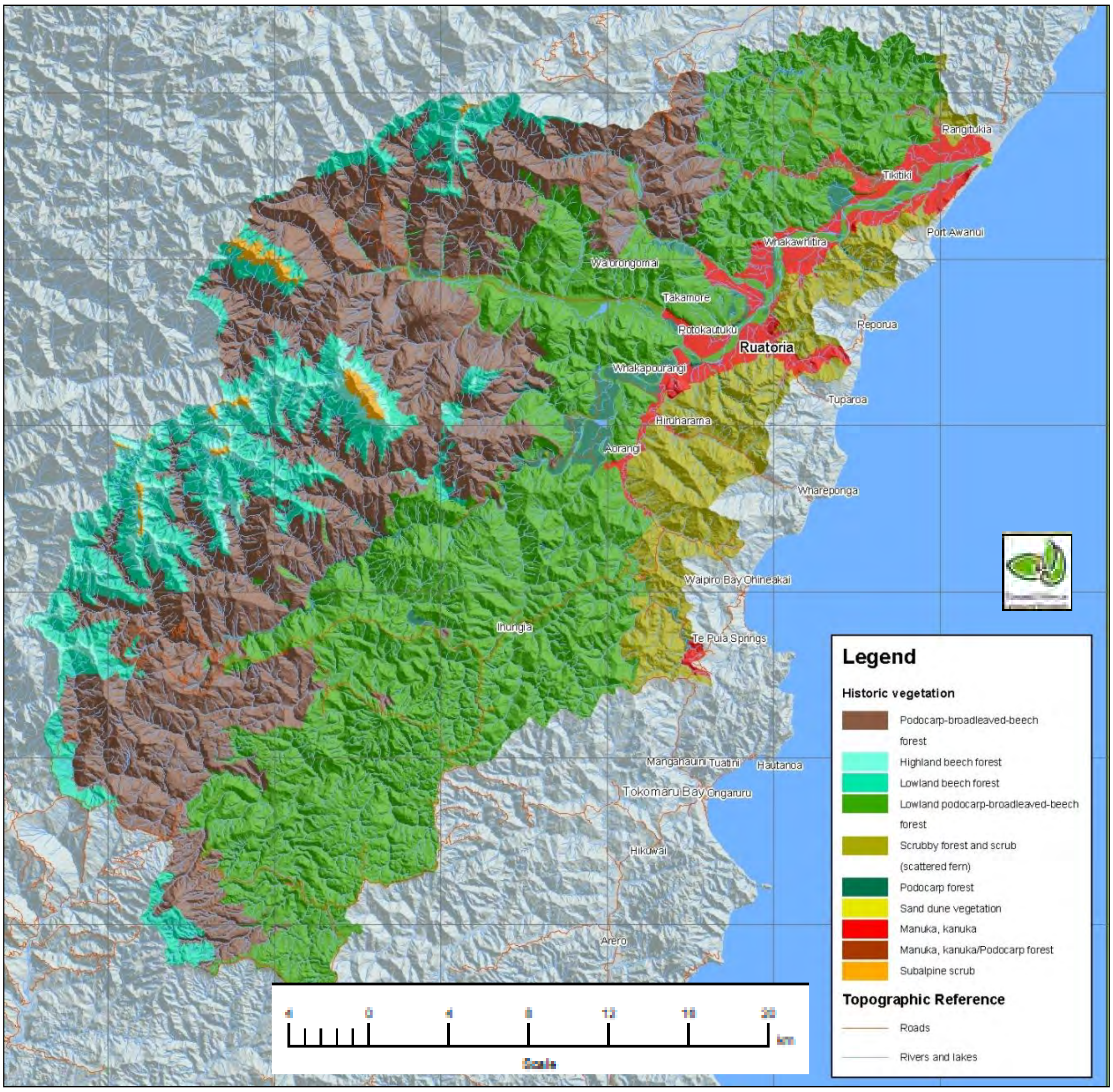

Figure 4.1. Vegetation cover map of the Waiapu catchment in 1840 (reproduced from Harmsworth et al., 2002).

Approximately 88% of the catchment was in primary forest in 1840, with about 11% in scrub and secondary forest. The area of scrubby forest and scrub occurred on the coastal hills, east of the Waiapu River as far south as Te Puia Springs, and resulted from partial clearance and burning. Manuka and kanuka dominated the terraces bordering the Waiapu River except for areas cultivated for food production.

4.3.2 Erosion

While there are no data on erosion prior to the commencement of deforestation, an interpretation of erosion status has been made from knowledge of the erosion processes and erosion rates that would likely have occurred under the vegetation cover described above, together with Ngāti Porou knowledge of conditions within the catchment obtained from interviews with tangata whenua (especially elders), and archived records (Harmsworth et al., 2002).

As described in the geophysical review (chapter 4), the combination of lithology, topography, and dynamic tectonic and climatic setting has resulted in a landscape with high natural erosion rates. However, under a largely unmodified forest cover these erosion rates were likely at least an order of magnitude lower than current rates. Numerous studies in similar terrains have shown that landsliding under natural forest cover is about ten times less than under pasture (Marden & Rowan, 1994; DeRose, 1996; Page & Trustrum, 1997). Based on written accounts of gully erosion in upper catchment areas, it is likely that gully initiation occurred within a decade or two following deforestation around the turn of the 19th century. Furthermore, the earliest aerial photography shows gully erosion to be largely absent from steepland areas of natural forest, suggesting it had been minimal in forested areas subsequently cleared for pastoral use (Marden et al., 2011). Rather than the current ongoing supply of sediment, largely from gullies, prior to deforestation erosion would have been less frequent and sediment supply would have been sporadic and driven by occasional but high magnitude storms and earthquakes. Evidence for this is provided by Cyclone Bola in 1988 when rainfall of between 700-900 mm over four days (estimated) caused massive erosion under natural forest within headwater catchments supplying the Tapuaeroa River (Liébault et al., 2005; Page et al., 2008). Earthflows would have been present in many areas where crushed and sheared rocks occur, although rates of movement would have been slower under the natural forest cover. A study in the neighbouring Waipaoa catchment has shown that large deep-seated landslides (in contrast to shallow, storm-rainfall-driven landslides), many 1000s of years old, are common in these landscapes, and may have contributed ~10% of sediment yield under forested landscapes (Page & Lukovic, 2011).

Several Ngāti Porou elders in interviews mentioned that following deforestation erosion increased: "When the trees were cut the land began to move; those are the ones that had the most slips, Waingakia, Mata, Ihungia, and Tapuaeroa".

4.3.3 River & sediment status

While there is no data on the condition of rivers and streams (nor on the bed load or sediment yield prior to deforestation), insights into conditions are available from Ngāti Porou oral history and a variety of archive sources. Mention is made that even in the 1930s the Waiapu River was narrower than today, and that children rode their horses across the river to school. Rivers were also used to transport wool and timber downstream. Anecdotal accounts suggest that the river and its major tributaries were able to support healthy populations of fish and eels (Harmsworth et al., 2002). Activities such as fishing, swimming, collecting drinking water and washing clothes were carried out in many rivers well into the 20th century, and the coastal waters were used extensively for fishing. This indicates that water quality was vastly better and sediment loads much lower than at present.

4.4 Catchment conditions at 1969

4.4.1 Vegetation

The 1969 distribution of different vegetation types in the Waiapu catchment and in each sub-catchment are shown in Table 4.3, and Figure 4.2. Prior to the establishment of plantation forests in the Waiapu in 1969, approximately half of the catchment area (88,132 ha) was in grassland/pasture, while 40% of the catchment area remained in natural forest and scrub (62,845 ha). Nearly 10% of the catchment area (16,406 ha) was occupied by grassland with scattered scrub. Natural forest occupied >50% of the land area in the Tapueroa, Motumako, Waitahaia, and Waingakia catchments, and pasture occupied >50% of the land area in the Waiapu (Ruatoria), Makatote, makarika, Ihungia, Upper and Lower Mata sub-catchments.

Table 4.3. Area (ha) of vegetation types at 1969 by sub-catchment.

Catchment	Natural Forest	Scrub	Grassland and Scrub	Grassland and Cropland	Other	Total
Tapuaeroa	16,533	864	2,872	10,322	2,254	32,845
Mangaoporo	2,560	335	1,764	2,935	492	8,086
Poroporo	833	744	1,960	3,101	189	6,827
Maraehara	1,530	2,089	802	3,457	146	8,024
Motumako	326	23	0	197	2	548
Waiapu (Ruatoria)	1,081	1,709	402	8,546	1,127	12,865
Makatote	365	3,348	94	3,016	250	7,073
Makarika	1,512	426	638	5,220	105	7,901
Ihungia	619	331	243	6,531	158	7,882
Upper Mata	4,333	1,417	4,202	29,211	474	39,637
Waitahaia	11,781	431	3,032	5,770	483	21,497
Lower Mata	3,146	421	397	8,729	566	13,260
Waingakia	5,993	95	0	1,097	210	7,395
Waiapu (whole catchment)	50,612	12,233	16,406	88,132	6,456	173,839

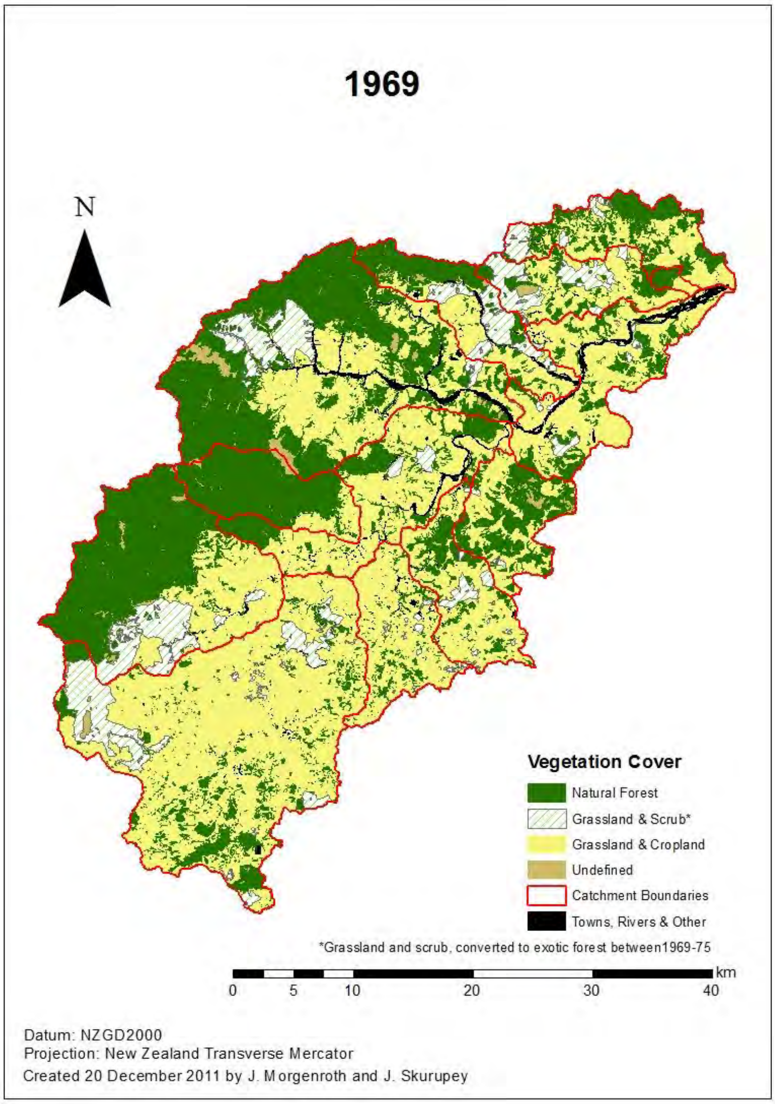

Figure 4.2. Vegetation cover in the Waiapu catchment in 1969.

4.4.2 Erosion

The amount and distribution of gullies in 1969 are represented by the gully mapping and modelling carried out by Landcare Research using aerial photography dated 1957. The gully model estimated that the suspended sediment yield in the Waiapu River in 1969 was 15.53 Mt. The gully model indicates that sediment yield from gullies could have increased by as much as 15% between 1957 and 1969, so we estimate that the numbers and areas of gullies may also have been about 15% higher in 1969 than in 1957. Based on this assumption, the total number of gullies in the catchment would have been approximately 1,690, and the total area of gullies was approximately 3,025 ha. However, it is not possible to estimate their distribution at the sub-catchment level in 1969 from the Landcare Research gully model. Instead numbers and areas of gullies are shown for 1957 based on the Landcare Research gully inventory (Marden et al., 2005) (Table 4.4). The sub-catchments with the greatest number and area of gullies in 1957, and probably also in 1969, were Tapuaeroa, Mangaoporo, Ihungia, Upper and Lower Mata, Makarika and Waitahaia (Figure 4.3).

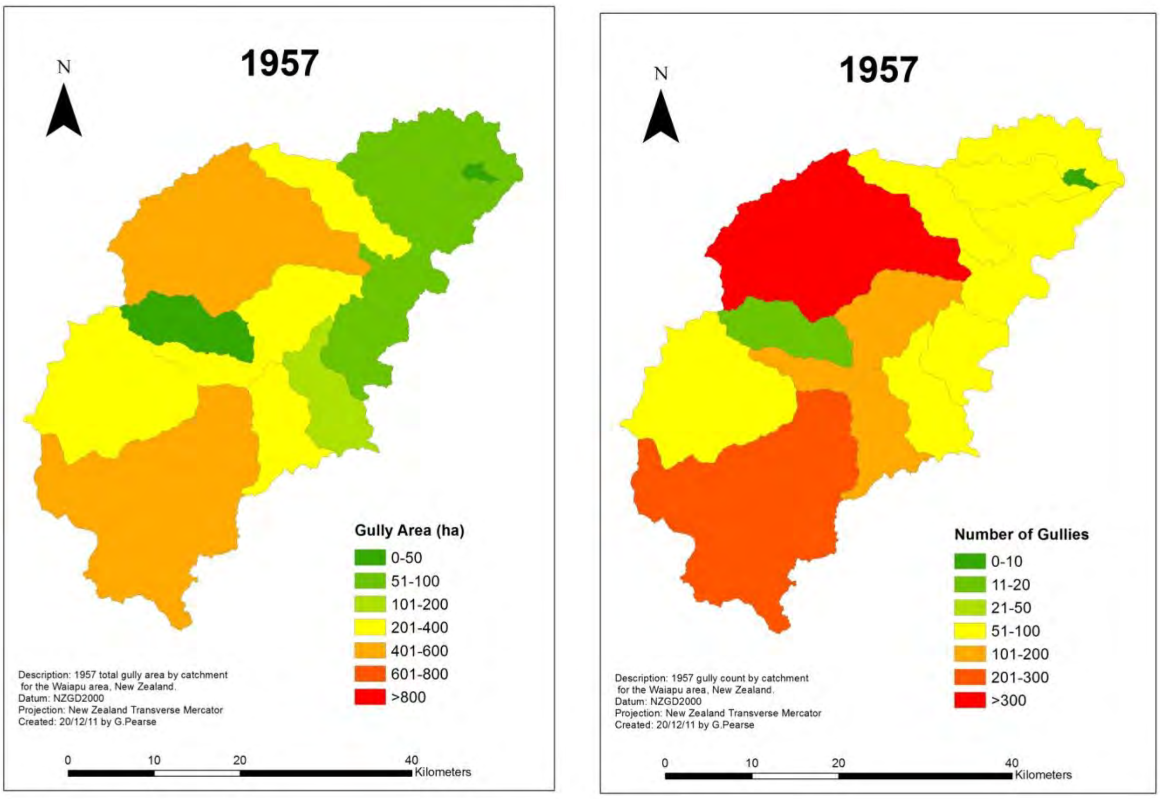

Figure 4.3. Area and numbers of gullies (by category) for Waiapu sub-catchments in 1957.

There were 1,353 small (<5 ha) gullies in 1957, 101 medium (5-15 ha) gullies, and 14 large gullies (>15 ha). Most of the medium and large gullies were located in the Tapuaeroa, Mangaoporo, Upper and Lower Mata sub-catchments. There were nearly 400 small gullies in the Tapuaeroa sub-catchment, and over 200 small gullies in the Upper Mata sub-catchment.

Table 4.4. Gully numbers, areas and size distribution as at 1957 in the Waiapu catchment, and sub-catchments.

Catchment name	Number of gullies	Gully area (ha)	# < 5 ha	# 5-15 ha	# > 15 ha
Tapuaeroa	415	558	393	21	1
Mangaoporo	83	263	65	17	1
Poroporo	75	78	74	1	0
Maraehara	67	81	64	3	0
Waiapu (Ruatoria)	89	96	88	1	0
Makatote	55	77	53	2	0
Makarika	91	156	88	3	0
Ihungia	118	253	108	8	2
Upper Mata	226	567	201	19	6
Waitahaia	63	207	48	12	3
Lower Mata	174	283	159	14	1
Waingakia	12	11	12	0	0
Kopuaroa	19	40	17	2	0
Mangapoi	30	31	29	1	0
Mangawhairiki	27	18	27	0	0
Raparaparirki	62	70	58	4	0
Weraamaia	20	52	17	3	0
Waiapu (whole catchment)	1,468	2,631	1,353	101	14

The areas of vegetation types on land with a potential erosion severity (PES) of 3 and over (i.e. severe, very severe, and extreme potential erosion severity) from the NZLRI (2nd edition) are listed in Table 4.5. In 1969, there were about 32,661 ha of land with PES 4 or 5 under grassland, and a further 8,398 ha under grassland with scattered scrub. It should be noted that land with severe potential severity (PES 3) is also likely to require intensive soil conservation measures to prevent significant erosion on this land (Lynn et al., 2009).

Table 4.5. Vegetation type (ha) by potential erosion severity in 1969.

1969 Vegetation by erosion class	Potential Erosion Severity			Total
	3	4	5	
Natural Forest and scrub	18,408	29,996	2,545	50,949
Planted forest	0	0	0	0
Grassland & Scrub*	4,133	8,380	18	12,531
Grassland + Cropland	14,159	32,403	258	46,820
Other forest	1,521	673	93	2,287
Other	84	577	104	765

* Converted to plantation forest 1969-1975.

4.4.3 Rivers

Below is a summary of conditions inferred for various rivers and streams based on evidence from cross sections in various reaches (for locations of cross-sections, refer to Peacock (2011)).

In 1969, the main-stem Waiapu River was aggrading at between 14-75 mm/yr between Ruatoria and Tikitiki. Major sub-catchments that were also aggrading were the Mangaoporo, Mangaraukokore (downstream), and Wairongomai. The Mangaoporo was aggrading at between 21-39 mm/yr. The earliest measurements available indicate that the Mangawhairiki (1979-1982) was rapidly aggrading at 1,289 mm/yr in the upstream reaches, and 369 mm/yr in the downstream reaches, most likely in response to the 1980 storm, and the Wairongomai (1979-1984) was aggrading at a rate 70-90 mm/yr. In 1969, the Tapuaeroa was incising at 60 mm/yr at the upstream end and 21 mm/yr at the downstream end (1968-1972), but aggrading at all other sections in between. Between 1979 and 1982, the Raparariki was incising at between 30-140 mm/yr (1979-1982), but aggrading at the most upstream section at a rate of 150 mm/yr. The earliest cross-sections on the Mangaraukokore (1977-1979) indicate that it was aggrading in the downstream reaches at 90 mm/yr, and incising in the upstream reaches at 140 mm/yr. Unanalysed data exists for other rivers and streams in the Waiapu catchment. However, these data were not analysed as part of the present study.

4.5 Catchment conditions at 1988

4.5.1 Vegetation

Vegetation data from LUCAS 1990 mapping has been used to represent the vegetation cover in the Waiapu catchment in 1988. The distribution of different vegetation types in the Waiapu catchment, and each sub-catchment, is shown in Table 4.6, and Figure 4.4. By 1988, nearly 12% of the catchment had been planted in protection forests (20,493 ha), and 47% of the catchment remained in grassland, and a further 4% in grassland with scattered scrub.

Table 4.6. Area (ha) of vegetation types at 1990 by sub-catchments.

Catchment	Natural Forest and Scrub	Planted Forest	Grassland and Scrub	Grassland and Cropland	Other	Total
Tapuaeroa	17,437	3,106	1,037	9,900	1,366	32,846
Mangaoporo	2,506	1,567	260	3,334	419	8,086
Poroporo	1,786	1,782	384	2,826	47	6,825
Maraehara	3,579	721	418	3,252	42	8,012
Motumako	352	0	1	193	2	548
Waiapu (Ruatoria)	3,199	289	478	7,752	1,134	12,852
Makatote	3,394	19	468	3,188	4	7,073
Makarika	1,729	801	605	4,672	93	7,900
Ihungia	522	238	501	6,453	168	7,882
Upper Mata	3,980	8,050	1,855	25,494	257	39,636
Waitahaia	12,605	2,896	339	5,530	127	21,497
Lower Mata	3,877	1,024	304	7,505	550	13,260
Waingakia	6,324	0	76	976	18	7,394
Waiapu (whole catchment	61,290	20,493	6,726	81,077	4,227	173,813

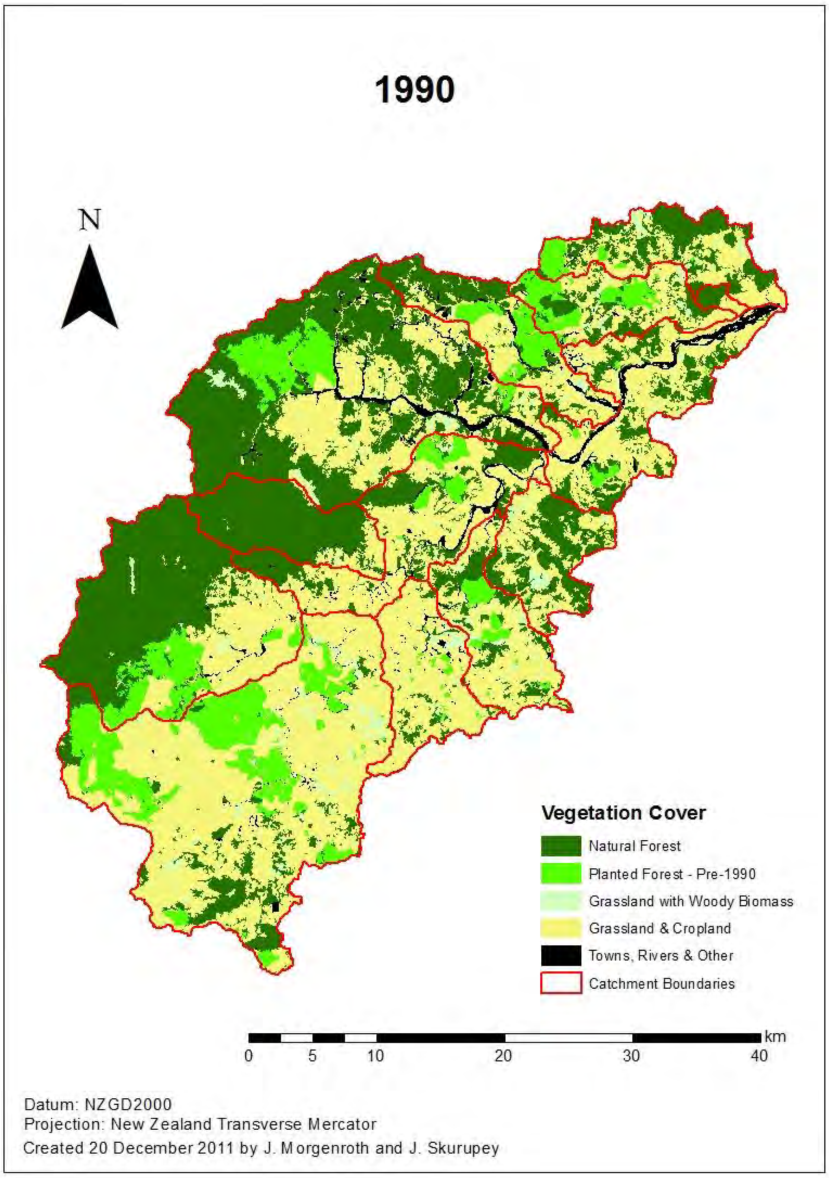

Figure 4.4. Vegetation cover in the Waiapu catchment in 1990.

4.5.2 Erosion

There is no catchment-wide gully information for the Waiapu catchment for 1988, but suspended sediment yield for the Waiapu was estimated at 19.06 Mt by the gully model (Herzig et al., 2011). This is a 23% increase on the modelled sediment yield of 15.53 Mt in 1969. For the period 1969 to 1988, the gully model estimated an average sediment yield of 18.69 Mt/yr, an increase of 22% from the previous modelling period (1957–1969).

In the headwaters of the Raparapaririki catchment there was a 350% increase in the area of landslides and associated gullying resulting from Cyclone Bola (Liébault et al., 2005).

In the Weraamaia catchment, sediment supply from landslides increased by ~80% as a result of Cyclone Bola (Kasai et al., 2005).

In 1988 (represented by the 1990 LUCAS data), the area of land with PES 4 or 5 under grassland or cropland was 29,362 ha (Table 4.7), a decrease of 3,299 ha from 1969. There were also 2,839 ha of land with PES 4 or 5 under grassland with woody biomass. Interestingly, there were 15,207 ha of planted forest on land with PES 3 or 4, but only 24 ha of planted forests on the worst eroding land with a PES of 5.

Table 4.7. Vegetation type (ha) by potential erosion severity in 1990.

1990 Vegetation	Potential Erosion Severity			Total
	3	4	5	
Natural Forest and scrub	18,735	29,052	2,150	49,937
Planted forest	4,629	10,577	24	15,230
Grassland - With woody biomass	1,518	2,801	38	4,357
Grassland + Cropland	13,252	28,781	581	42,614
Other	170	816	225	1,211

4.5.3 Rivers

Below is a summary of conditions inferred for various rivers and streams based on evidence from cross sections in various reaches (for locations of cross-sections, refer to Peacock (2011)).

4.5.3.1 Pre Bola (1982-1986)

Prior to Cyclone Bola, the Raparapaririki Stream was already rapidly aggrading 543 mm/yr in the upstream reaches and 189 mm/yr in the downstream reaches, most likely in response to Cyclone Bernie in 1982. The main-stem Waiapu was aggrading between 42-189 mm/yr near Ruatoria, but was incising at 32 mm/yr in the lower reaches near Tikitiki. The Mangaoporo was also rapidly aggrading at 166 mm/yr in the upstream reaches, and incising slightly at 11 mm/yr in the downstream reach.

The Tapuaeroa was incising at 68 mm/yr in the upstream reaches before Cyclone Bola, and relatively stable at the downstream end. The Mangawhairiki was incising at 92 mm/yr in the upstream reaches, and 281 mm/yr in the downstream reaches.

4.5.3.2 Post Bola (1988-1993)

In the years following Cyclone Bola (1987-2003), massive sediment inputs from gully and landslide erosion in the Raparapaririki catchment caused rapid aggradation at a rate of 2070 mm/yr in the upstream reaches of the Raparapaririki Stream, and 398 mm/yr in the downstream reaches (1987-1993). The most upstream cross-section aggraded by 33.5 m from 1987-2004. The Mangaraukokore also began to aggrade rapidly at 200-380 mm/yr. The Tapaueroa was aggrading at 172 mm/yr in upstream reaches, but was incising at 28 mm/yr in the downstream reach. The Mangaoporo was also aggrading at 22 mm/yr in the upstream reach, and stable in the downstream reaches. The Mangawhairiki was aggrading at 63 mm/yr at the upstream end, but was incising slightly (at 2 mm/yr) at downstream end (1987-2004).

Cyclone Bola caused incision between 13-94 mm/yr in the lower reaches of the main-stem Waiapu between Ruatoria and Tikitiki.

4.6 Catchment conditions at 2008

4.6.1 Vegetation

The 2008 distribution of different vegetation types in the Waiapu catchment, and each sub-catchment, is shown in Table 4.8, and Figure 4.5. By 2008, 25% of the catchment (43,733 ha) had been planted in plantation forests, and the area of grassland/pasture had decreased from 50% in 1969 to 35% in 2008. Nearly 35% of the catchment remains in natural forest. The sub-catchments with greater than 30% of their catchment areas in planted forests include Mangaoporo, Pororporo, Makarika, Ihungia, and Upper Mata. The greatest percentage of planting has occurred in the Ihungia sub-catchment, where >70% of the catchment area has been planted in protection forests (although, there is also the least amount of natural forest remaining in the Ihungia catchment: 6.5%).

Table 4.8. Area (ha) of vegetation types at 2008 by sub-catchment.

Catchment	Natural Forest and scrub	Planted Forest	Grassland and Scrub	Grassland and Cropland	Other	Total
Tapuaeroa	17,247	5,725	972	7,721	1,181	32,846
Mangaoporo	2,487	2,690	159	2,411	338	8,085
Poroporo	1,587	2,887	247	2,086	21	6,828
Maraehara	3,573	1,307	311	2,780	42	8,013
Motumako	352	0	1	193	2	548
Waiapu (Ruatoria)	2,897	1,097	461	7,323	1,075	12,853
Makatote	3,138	864	313	2,757	1	7,073
Makarika	1,697	2,420	277	3,438	69	7,901
Ihungia	513	5,533	90	1,730	16	7,882
Upper Mata	3,838	14,481	1,794	19,348	176	39,637
Waitahaia	12,602	3,220	412	5,155	108	21,497
Lower Mata	3,849	3,509	363	5,086	453	13,260
Waingakia	6,324	0	87	966	18	7,395
Waiapu (whole catchment)	60,104	43,733	5,487	60,994	3,500	173,818

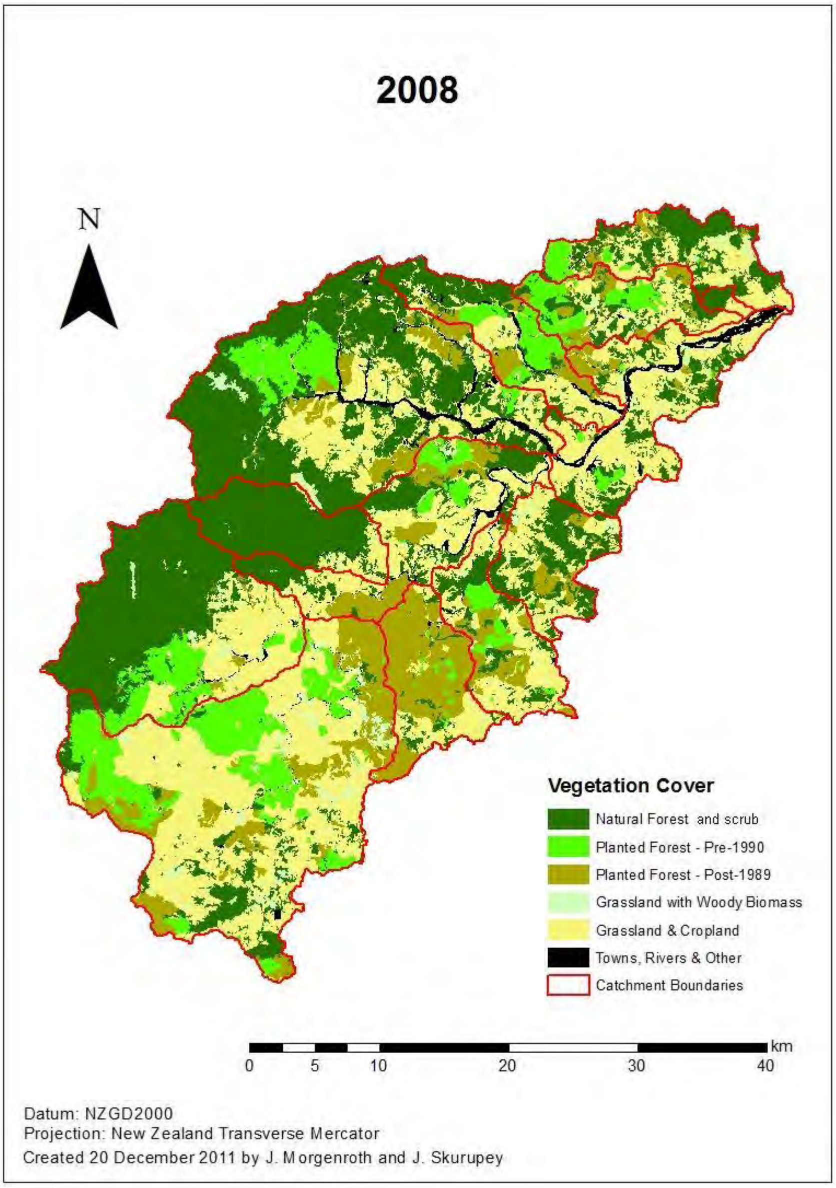

Figure 4.5. Vegetation cover in the Waiapu catchment in 2008.

4.6.2 Erosion

Gully numbers and area in 2008 for the Waiapu catchment and sub-catchments are listed in Table 4.9. Herzig et al. (2011) updated the 1997 gully map to 2008 using SPOT5 satellite imagery to identify new forestry planting which would have shut down existing gullies. The 2008 gully database was based on the 1997 gully distribution, and included randomly occurring newly initiating gullies as predicted by the gully-complex model (i.e. new gullies were not actually mapped). The area and number of gullies (by category) for Waiapu sub-catchments are shown in Figure 4.6.

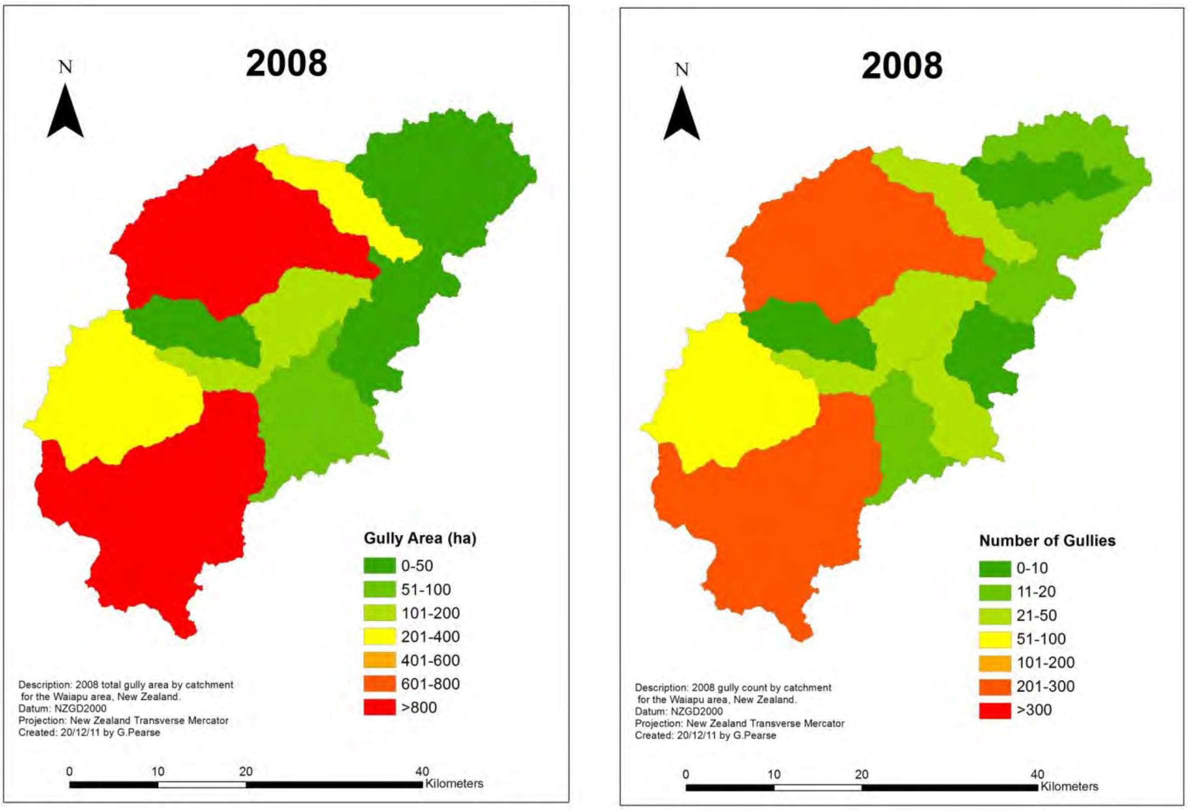

Figure 4.6. Area and Number of gullies (by category) for Waiapu sub-catchments in 2008.

Table 4.9. Gully numbers, areas and size distribution as at 2008 in the Waiapu catchment, and sub-catchments.

Catchment name	Number of gullies	Gully area (ha)	# < 5 ha	# 5-15 ha	# > 15 ha
Tapuaeroa	231	1325	162	44	25
Mangaoporo	45	309	25	14	6
Poroporo	7	29	5	2	0
Maraehara	12	24	11	1	0
Waiapu (Ruatoria)	14	38	12	2	0
Makarika	24	77	20	3	1
Ihungia	16	80	12	2	2
Upper Mata	203	803	159	32	12
Waitahaia	73	226	60	13	0
Lower Mata	50	148	40	10	0
Waingakia	8	14	8	0	0
Mangapoi	31	196	20	6	5
Mangawhairiki	14	58	11	1	2
Raparaparirki	43	365	27	8	8
Weraamaia	1	5	0	1	0
Waiapu (whole catchment)	683	3,073	514	123	46

In 2008, there were 683 gullies in the Waiapu catchment, with a combined area of 3,073 ha. The suspended sediment yield from gullies was estimated at 23.97 Mt by the gully complex model, an increase of 26% from the 1988 sediment yield of 19.06 Mt. There were 514 small gullies (<5 ha), 123 medium gullies (5-15 ha), and 46 large gullies (>15 ha). The gullies >20 ha in size are considered too large to be treated by afforestation (Marden et al., 2008, 2011). The sub-catchments with the greatest number and area of gullies were the Tapuaeroa, Mangaoporo, Upper and Lower Mata, Waitahaia, Mangapoi, and the Raparaparirki.

In 2008, the area of land with PES 4 or 5 remaining in grassland or cropland was 19,400 ha (Table 4.10), a decrease of 9,962 ha from 1988. The area of PES 4 or 5 land under grassland with woody biomass was 2,106 ha, representing a decrease of 733 ha from 1988. There were 31,348 ha of planted forests on land with PES 3 or 4. Interestingly, there was still only a very small area (173 ha) of planted forests on the worst eroding land with a PES of 5.

Table 4.10. Vegetation type (ha) by potential erosion severity in 2008.

2008 Vegetation	Potential Erosion Severity			Total
	3	4	5	
Natural Forest and scrub	18,399	28,700	2,148	49,247
Planted forest	9,313	22,035	173	31,521
Grassland - With woody biomass	1,295	2,068	38	3,401
Grassland + Cropland	9,199	18,871	529	28,599
Other	99	353	128	580

4.6.3 Rivers

Below is a summary of conditions as at 2007, inferred for various rivers and streams based on evidence from cross-sections in various reaches (for locations of cross-sections, refer to Peacock (2011)).

The latest cross sections on the Waiapu River indicate that it was aggrading at between 38-115 mm/yr in the lower reaches between Ruatoria and Tikitiki (2003-2007). The Tapuaeroa was aggrading at between 116-151 mm/yr in the upstream reaches and between 52-58 mm/yr in the downstream reaches (2003-2007). The Mangaoporo was aggrading at between 58-66 mm/yr in the upstream reaches and incising at between 5-51 mm/yr in the downstream reaches. The Wairongamai was aggrading at a rate of 10-80 mm/yr (1993-2004). The Mangapoi was aggrading at 43 mm/yr in the upstream reach and incising at 131 mm/yr in the downstream reach.

The Raparapaririki has begun to incise at between 13-185 mm/y in the upstream reaches, but aggradation at between 13-75 mm/y is occurring in downstream reaches. A similar pattern of incision in the upper reaches, and aggradation in the lower reaches was recorded for the Mangawairiki, where it was incising at 111 mm/yr in upstream reaches and aggrading 18 mm/yr in downstream reaches.

4.7 Trends in catchment conditions

4.7.1 Vegetation

Between 1969 and 2008 the area of natural forest and scrub (blocks of closed canopy scrub), has decreased by only ~4%. The area of grassland and scrub (scrub scattered through grassland), has decreased by ~67%, and grassland (including minor cropland) has decreased by ~31%. These decreases have been almost entirely due to the establishment of planted (exotic) forest (mainly *Pinus radiata*). The area of planted forest is now 43,733 ha. This total was derived from 2008 LUCAS mapping, and differs from the 2011 MAF East Coast Forestry Project (ECFP)-derived total for planted forest of 54,167 ha as reported in the geophysical literature review. Approximately 3,200 ha were planted between 2008 and 2011, and the remaining difference of ~7000 ha may result from areas of reversion under the ECFP being included within the Natural Forest category in the 2008 LUCAS mapping. Planted forest now covers ~25% of the whole Waiapu catchment. Sub-catchments with the highest percentage of planted forest (>30%) are the Ihungia, Poroporo, Upper Mata, Mangaoporo, and Makarika (Table 4.11) (Figure 4.7).

Table 4.11. Area and percentage of sub-catchments in planted forest at 2008.

Catchment	Catchment area (ha)	Planted Forest (ha)	Catchment planted (%)
Tapuaeroa	32,846	5,725	17.4
Mangaoporo	8,085	2,690	33.2
Poroporo	6,828	2,887	42.2
Maraehara	8,013	1,307	16.3
Motumako	548	0	0
Waiapu (Ruatoria)	12,853	1,097	8.5
Makatote	7,073	864	12.2
Makarika	7,901	2,420	30.6
Ihungia	7,882	5,533	70.1
Upper Mata	39,637	14,481	36.5
Waitahaia	21,497	3,220	14.9
Lower Mata	13,260	3,509	26.4
Waingakia	7,395	0	0
Waiapu (whole catchment)	173,818	43,733	25.1

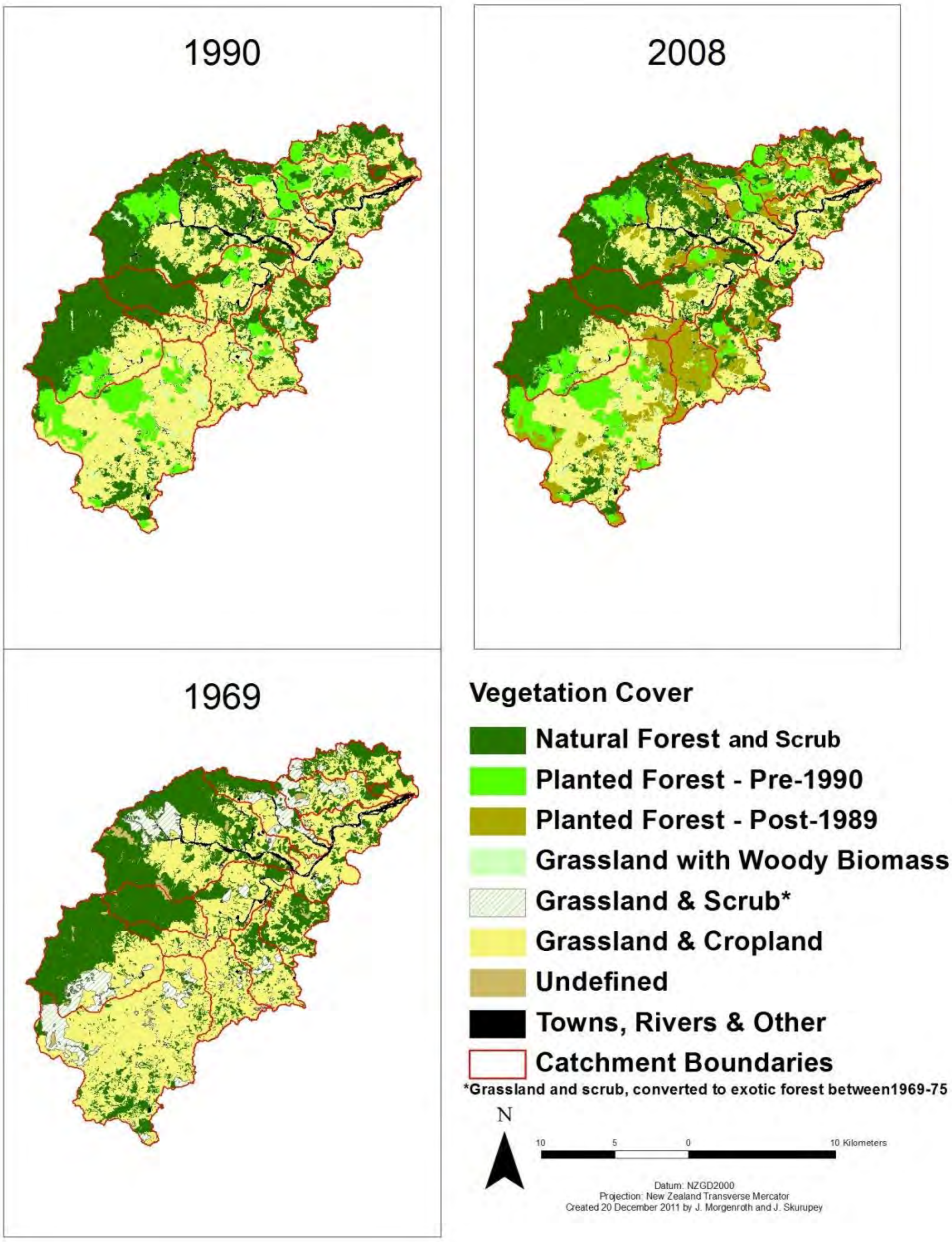

Figure 4.7. Land use maps for 1969, 1988, and 2008.

4.7.2 Erosion

Between 1969 and 2008 the sediment yield from gullies, increased from 15.53 Mt to 23.97 Mt, an increase of 54% (based on the gully model). Statistics on gully numbers, area, and size distribution are not available for 1969 or 1988. However, the number of gullies decreased from 1,468 in 1957 to 683 in 2008, whereas the total area of gullies increased from 2,631 ha to 3,073 ha. The increase in total gully area was due to the number of unplanted gullies that increased in size (i.e. the increasing number of medium and large-sized gullies) (Table 4.12). Although, the number of medium-sized gullies (5-15 ha) and large gullies (>15 ha) have decreased from a maximum in 1997 (Table 4.12).

Table 4.12. Gully numbers, area, size, and sediment yield for the Waiapu catchment for 1957, 1997, and 2008 (data from Landcare Research).

Waiapu catchment	1957	1997	2008
Sediment yield from gullies (Mt)	13.49	20.86	23.97
Total no. of gullies	1,468	966	683
Total area of gullies	2,631	3,893	3,073
# <5 ha	1,353	749	514
# 5-15 ha	101	164	123
# > 15 ha	14	53	46
# gullies in Cretaceous terrain	1,057	599	457
Area of gullies in Cretaceous terrain (ha)	1,902	2,633	2,148
# gullies in Tertiary terrain	411	367	226
Area of gullies in Tertiary terrain (ha)	729	1,260	925

Data on a sub-catchment basis is given in Appendix 4. Most sub-catchments showed a decreasing trend from 1957-2008 in the number of gullies (Figures 4.8 and 4.9), with the exceptions of the Waitahaia and Mangapoi sub-catchments. Sub-catchments that showed a marked decline in the number of gullies were the Tapuaeroa, Mangaoporo, Poroporo, Maraehara, Waiapu (Ruatoria), Makarika, Ihungia, Lower Mata, and Weraamaia. The marked decline in the number of gullies was matched by a marked decline in gully area in the Poroporo, Maraehara, Waiapu (Ruatoria), Makarika, Ihungia, Lower Mata, and Weraamaia. Sub-catchments that showed a decline in gully number, but an increase in gully area were Tapuaeroa, Mangaporo, Upper Mata, Waitahaia, Mangapoi, Mangawhairiki, and Raparapaririki. This was due to the medium to large-sized gullies getting bigger.

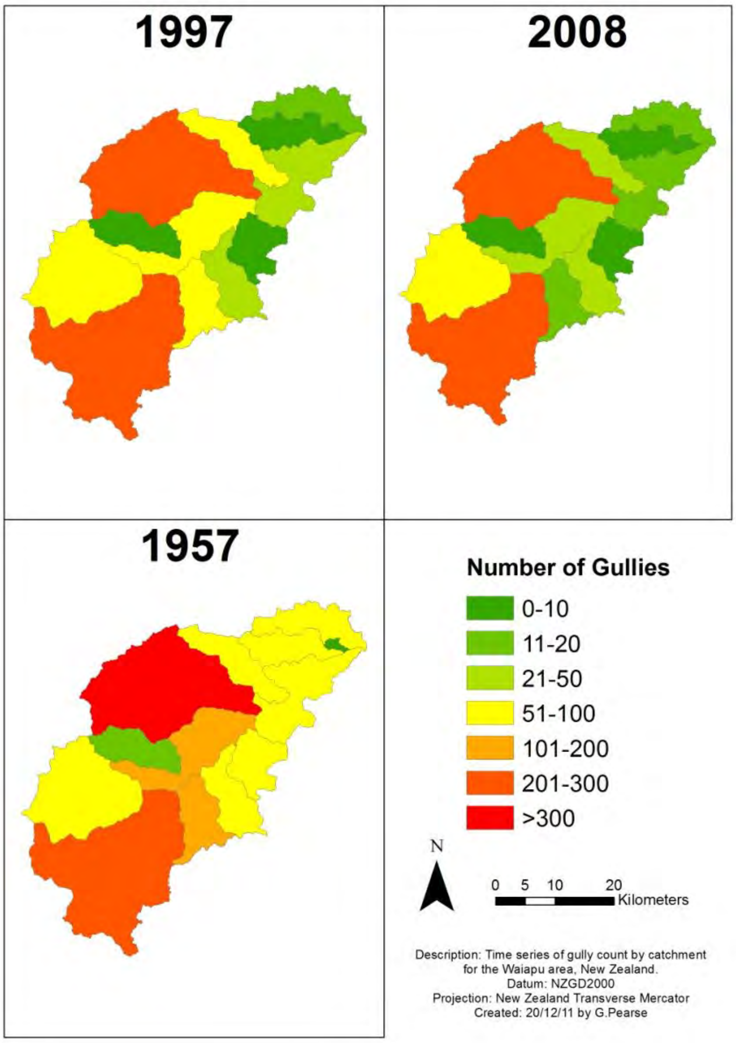

Figure 4.8. Number of gullies (by category) for Waiapu sub-catchments in 1957, 1997 and 2008.

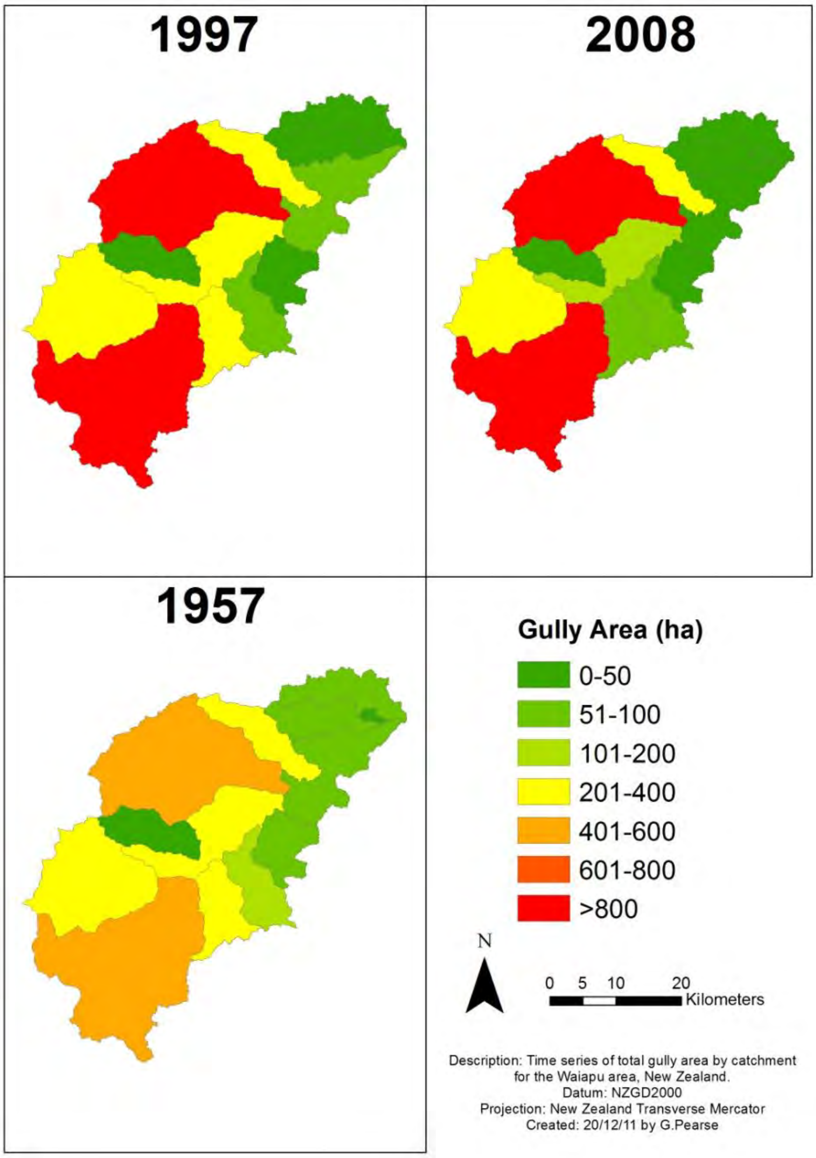

Figure 4.9. Area of gullies (by category) for Waiapu sub-catchments in 1957, 1997, and 2008.

All sub-catchments except the Waitahaia showed a decline in the number of small gullies from 1957 to 2008. However, the number of medium-sized gullies increased in the Tapuaeroa, Upper Mata, Waitahaia, Mangapoi, Mangawhairiki, and Raparapaririki, and the number of large gullies increased in Tapuaeroa, Upper Mata, Mangapoi, Mangawhairiki, and Raparapaririki sub-catchments over the same period. This is the result of insufficient afforestation in these sub-catchments.

The number of Cretaceous gullies decreased in all sub-catchments except for the Waitahaia and Mangapoi, but the area of Cretaceous gullies increased in the Tapuaeroa, Mangaporo, Waitahaia, Mangapoi, Mangawhairiki, and Raparapaririki. The number of Tertiary gullies decreased in all sub-catchments, but the area of Tertiary gullies increased in the Tapuaeroa, Maraehara, and the Upper Mata (due to the growth of medium and large-sized gullies).

Table 4.13 shows that the area of land with PES 4 or 5 (very severe or extreme) remaining in grassland (excluding areas of grassland with woody biomass) has decreased from 32,661 ha in 1969 to 19,400 ha in 2008. Concurrently, the area of land with PES 4 or 5 that has been planted in forest increased from zero in 1969 to 22,208 ha in 2008. However, the 19,400 ha remaining in pasture is at risk of mass movement erosion. The majority of the area of planted forest on PES 4 or 5 land in 2008 was on PES 4 land, with only 174 ha on PES 5 land (extreme potential erosion severity).

Table 4.13. Trends in the area of grassland vs. planted forest from 1969, 1990, and 2008 on land with potential erosion severity of 4 or 5.

Vegetation	1969	1990	2008
Grassland	32,661	29,362	19,400
Planted forest	0	10,601	22,208

4.7.3 Rivers

Seven rivers in the Waiapu catchment have cross-section data that has been analysed, with sufficient length of record or number of cross-sections to identify aggradation/incision trends that are related to afforestation. Analysis of these cross-sections show that some of the river channels in the Waiapu catchment (Tapuaeroa, Mangawhairiki, Mangaraukokore) were incising immediately prior to Cyclone Bola in 1988. However, most channels (Waiapu, Mangaoporo, Raparapaririki, Mangapoi, Makarika, and Wairongomai) were already rapidly aggrading in response forest clearance and large storm events in 1980 and 1982. Following Cyclone Bola, most of the river channels rapidly aggraded (Tapuaeroa, Mangaoporo, and Raparapaririki), with extreme rates of aggradation (up to ~2.5 m/yr) measured in the Raparapaririki Stream from 1987 to 2003. In the most recent period captured by cross-section surveys, the larger rivers are still aggrading (Waiapu, Tapuaeroa, Mangaoporo, and Wairongoma). However, incision has started to be recorded in the upper reaches of smaller sub-catchments (Raparapaririki, Mangawhiriki, Makarika, and Weraamaia) and is slowly proceeding to downstream reaches. Channel widths have been increasing in all monitored rivers in the Waiapu catchment, with rapid increases in channel width recorded in the Waiapu, Raparapaririki, and Mangawhairiki.

A case study in a small headwater catchment (Weraamaia) has shown that deforestation led to rapid aggradation and widening of stream channels within 30-40 years, and following afforestation, equally rapid incision. A case study in a medium-sized catchment (Raparapaririki) has shown that even under steep, naturally forested conditions, once a threshold condition is passed, severe erosion can occur resulting in very rapid stream aggradation, and that stream incision can occur within 16 years as hill slope sediment sources are exhausted or revegetated.

While both channel aggradation, in response to erosion caused by deforestation and by major storms, and channel incision, in response to afforestation, have been rapid (years to decades) in headwater catchments, the likelihood and rate at which incision will proceed downstream is unknown and will depend on the amount and timing of future afforestation and storm events.

4.8 Scope assessment – size & scale of the erosion problem

Current annual sediment yields from the Waiapu River are very large in comparison to other rivers in New Zealand. Annual sediment yields from selected rivers in New Zealand were derived from Hicks et al. (2011) and are presented in Table 4.14. Sediment yields in Table 4.14 are expressed in units of mass per year (Mt/yr) as well as on a mass per unit area per year basis (t/km^2/yr). On a mass per unit area per year basis, the annual sediment yield from the Waiapu River (20,520 t/km^2/yr) is more than 20 times greater than those of the other rivers listed with the exceptions of the Waipaoa, Arawhata, and Hokitika rivers, in comparison to which, the sediment yield of the Waiapu River is three to four times greater.

Table 4.14. Annual sediment yields of selected New Zealand rivers (derived from Hicks et al., 2011).

Location	River	Sediment yield (t/km^2/yr)	Sediment yield (Mt/yr)
North Island	Waiapu	20,520	35.07
	Waipaoa	6,646	14.66
	Whanganui	665	4.70
	Manawatu	636	3.74
	Rangitikei	280	1.10
	Waikato	37	0.53
South Island	Arawhata	7,687	7.18
	Hokitika	5,429	6.20
	Rangitata	933	1.60
	Waimakariri	879	3.14
	Waiau	842	2.80
	Clutha	113	2.39
	Waitaki	58	0.69

Despite about 54,000 ha (data supplied by MAF – GDC office) of afforestation in the Waiapu catchment to date, the area of gullies, and the sediment yield in the river continues to increase. The scale of the erosion problem at present in the Waiapu catchment can be represented by the area of untreated land with Potential Erosion Severity (PES) of 4 or 5, plus the area of gully-prone land without effective tree cover that is not included within the area of land with a PES of 4 or 5.

In 2008, there were 14,300 ha of unplanted gullies (excluding gullies >20 ha), and their associated catchments (A. Herzig, pers. comm.). Of this area, 8,328 ha were not included within the ECFP target area. The area of unplanted gullies and their associated catchments including gullies >20 ha was 21,659. As at 2008, there were 683 gullies, with a combined area of 3,073 ha. There were 514 small gullies (<5 ha), 123 medium gullies (5-15 ha), and 46 large gullies (>15 ha). The sub-catchments with the greatest number and area of gullies are the Tapuaeroa, Mangaoporo, Upper and Lower Mata, Waitahaia, Mangapoi, and the Raparaparirki. Small and medium sized gullies are able to be controlled by afforestation, but the gullies >20 ha in size are considered too large to be treated by afforestation (Herzig et al. 2011). Herzig et al. (2011) found that if all gullies were to be afforested by 2020, the sediment yield from gullies could be reduced by half (from 22 Mt/yr to 11 Mt/yr) by 2050, but if afforestation efforts were terminated today, and new gullies were also left untreated, the sediment yield from gullies would double (to 45 Mt/yr) by 2050. To achieve effective erosion control, both gullies, and adjacent areas must be treated. This will most likely incorporate the whole surrounding catchment, although perhaps not in all cases (e.g. where gully size is small relative to the size of the surrounding catchment). The area of each catchment to be treated would require assessment on a catchment by catchment basis. Sediment derived from gullies makes up 49% of the annual average sediment yield. The remaining 51% of the sediment yield is derived from other erosion processes such as landslide, earthflow, sheetwash, stream bank erosion, and river bed degradation. The contribution from each of these processes is unknown. In 2008 there were 19,400 ha of grassland (LUCAS 2008 data; http://www.mfe.govt.nz/issues/climate/lucas/) with PES of 4 or 5 that required effective tree cover (afforestation, reversion, and wide-spaced tree planting). This total includes areas of gully-prone ECFP target land. Given the nature of the available datasets we are unable to calculate the area of PES 4 or 5 land affected by these other erosion processes that requires treatment.

The net area of land within the Waiapu catchment that encompasses all grassland with a PES of 4 or 5 and all gullies and their associated catchments under grassland (excluding gullies > 20 ha which are too large to stabilise) as at 2008 was estimated to be up to a maximum of about 28,000 ha. This estimate was derived by adding the area of PES 4 or 5 land within the catchment that was under grassland (19,400 ha) to the area of gullies and their associated catchments under grassland not included within the ECFP target area (8,328 ha). All ECFP target land has a PES of 4 or 5. However, geospatial analysis (involving the intersection of NZLRI and LUCAS 2008 data) has indicated that there were approximately 4,000 ha of Land Use Capability (LUC) class 7e1 and 7e6 land under grassland (as at 2008) in the catchment with a PES of 4 or 5 that is not included within the ECFP target area. Therefore, there may be up to a maximum of about 4,000 ha of overlap between the area of PES 4 or 5 land and the area of gullies and their associated catchments under grassland not included within the ECFP target area. This means that the net area could be as low as about 24,000 ha, but it is unlikely to be this low because it is expected that not all of the approximately 4,000 ha of the PES 4 or 5 land in question will overlap with the area of gullies and their associated catchments under grassland.

4.8.1 Uncertainties

4.8.1.1 Climate variability

The Waiapu catchment has amongst the highest magnitude and frequency of rainstorms in the North Island. Erosion-inducing storms have a recurrence interval of 2.6 years in the headwaters and 3.6 years at the coast (Hicks, 1995). From the late 1800‘s to 2011 there have been ~57 rainfall events that have caused erosion damage and/or flooding. Cyclone Bola in 1988 and the 1938 storm were the two largest and most damaging events. However, a record of only ~130 year is unlikely to represent the range of natural variability in storm magnitude and frequency, therefore limiting our ability to assess the future likelihood of rainstorm events occurring or the likelihood of even more damaging events.

The magnitude and frequency of rainstorm events on the East Coast over the last 7,000 years has recently been established from analysis of sediments in Lake Tutira north of Napier (Page et al., 2010, Orpin et al., 2010, Palmer et al. 2010), and related to El Niño-Southern Oscillation (ENSO) and Southern Annular Mode (SAM) climate systems and their interaction (Gomez et al., 2011). The record identifies numerous ―stormy periods”, several of which were stormier than the last 130 years period. The record also identifies at least seven events larger than Cyclone Bola based on sediment thickness (Orpin et al., 2010).

4.8.1.2 Another Cyclone Bola

The impact of Cyclone Bola on the Waiapu catchment has never been assessed. While this makes assessing the impact of another similar event more difficult, some inferences can be made from studies in the adjacent Waipaoa catchment. The Waiapu catchment is of similar size to the Waipaoa catchment, but with more than twice the number and area of gullies. In 1988 the Waiapu catchment had about twice the area of forest and scrub. The Cyclone Bola sediment yield in the Waipaoa catchment was more than twice the annual average yield. On this basis the Cyclone Bola sediment yield for the Waiapu catchment may have been about twice (~70 Mt) the annual average yield (35 Mt). In the Waipaoa catchment, landslides contributed more sediment (~64%) than gullies during Cyclone Bola (Page et al., 1999), and sediment yields remained elevated for about three years thereafter (Hicks et al., 2000). This indicates that landslide terrain in the Waiapu catchment may contribute more sediment than gullies during an event of this magnitude.

The sediment yield from another event of similar magnitude to Cyclone Bola is likely to be somewhat less than it was in 1988, and depend primarily on the increase in the area, and location of effective tree cover that has been established between the events. Planted forest now covers ~25% of the Waiapu catchment. Combined with the area in indigenous forest (34%), over half (59%) of the catchment is now covered in woody biomass. However, gully erosion did occur under natural forest following Cyclone Bola in 1988, where storm rainfall was likely between 700 and 900 mm. Given the demonstrated importance of landslide erosion to the Cyclone Bola sediment yield in the Waipaoa catchment, the amount of landslide-prone land without effective tree cover would have a significant influence on the sediment yield from future large storms.

4.8.1.3 Climate change

In addition to natural climate variability, human-induced global warming is forecast to lead to changes in climate during the 21st century. NIWA have modelled regional changes in annual, seasonal, and extreme rainfalls for New Zealand (Tait, 2011), based on the scenario of a 2°C increase in temperature associated with an increase in greenhouse gas emissions as reported in the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (IPCC, 2007).

Projected annual precipitation changes for the area north of Gisborne between 1990 and 2090 are for a decrease of up to 5%, dominated by changes in winter and spring. By the middle of the century, eastern areas are likely to spend around an additional 10% of the year in drought, and by the end of the century up to a doubling of the time spent in drought. However, climate change is also expected to lead to increases in the frequency and intensity of extreme rainfall. For a 2°C warming, the 100-year average recurrence interval 24-hour rainfall total is projected to increase by around 50-90 mm for most of the Waiapu catchment.

Therefore, while there will always be uncertainty around the size of the next storm and when it will occur, the studies outlined above indicate that erosion-inducing rainfall events in the Waiapu catchment can be expected to increase over the coming century. To avoid a resulting increase in erosion (and sediment yield), will require additional tree planting (afforestation, reversion, and wide-spaced tree planting) of erosion-prone land.

4.8.1.4 Earthquakes

The impact of a large magnitude earthquake on erosion and sediment yield are unknown, and it is recommended that these be assessed for any future event.

Hancox et al. (1997, 2002), in a study of 22 historical earthquakes that have generated substantial landsliding throughout New Zealand, defined relationships between landslide distribution and earthquake magnitude, epicentre, MM isoseismals, fault rupture zone, topography and geology, and identified threshold levels for landsliding. The magnitude threshold level for shallow landsliding is about M5, with large, deep-seated landsliding occurring at M6 or greater. For the New Zealand MM Intensity scale (ground shaking intensity), the threshold for shallow landsliding is MM6, while large deep-seated landsliding can be expected at MM7-MM8. While magnitude threshold levels have not been specifically identified for gullies, it is likely that they would be similar.

The 1929 Murchison (northwest Nelson-Buller) earthquake (M_w7.8, ≤ MM10) provides a rough analogy of the possible impact of a large earthquake on erosion and sediment yield in the Waiapu catchment. The affected area has steep, forested mountains and hills underlain by Tertiary sediments, Pleistocene gravels, and granitic and older sedimentary rocks. Landslides were largest and most common on 20°-50° slopes (especially dip slopes), on Tertiary mudstones and sandstones and weathered, well-jointed granite. Most landslides were associated with MM9 and MM10 shaking. The total area affected by landsliding was ~7000 km^2 (four times the area of the Waiapu catchment), and the total number of landslides (all sizes) was estimated to be close to 10,000. The overall volume of landslide debris may be as high as 2 $x10^9$ m^3 (~2 km^3) (Hancox et al., 2002).

No estimates of ground shaking return times have been made for the Waiapu catchment. However, Litchfield et al. (2009) have calculated return times for high levels of strong ground shaking (≥ 7 Modified Mercalli Intensity, MMI) for the adjacent Waipaoa and Waimata catchments. For relatively small areas (~90 km^2), return times are ~26 yrs (MM7), ~96 yrs (MM8), and ~420 yrs (MM9), while for ground shaking over large areas (~750 km^2), return times are ~130 yrs (MM7), ~620 yrs (MM8), and ~10,000 yrs (MM9). The NW and SE halves of the catchment have different return times due to the different contributions of the following active fault sources: the northern part of the North Island Dextral Fault Belt, normal faults in the central and eastern Raukumara Range, offshore thrust faults, and the subduction interface. It is likely that return times for the Waiapu catchment are similar or slightly longer (N. Litchfield, pers. comm.).

4.9 Critical evaluation of past and current erosion mitigation measures

The erosion mitigation techniques of afforestation, reversion, and wide-space planted trees are all effective for reducing erosion under appropriate conditions. Modelled sediment yields show that afforestation has reduced sediment yields by 17% from what it would have been without any afforestation. However, despite the establishment of about 54,000 ha of forest under current and past initiatives to control erosion (afforestation by NZ Forest Service (1969-1991), afforestation by the private sector (including Māori landowners) funded by soil conservation subsidies (1960s to late 1980s), or the ECFP (1993 onwards), gully sediment yield has increased by 78% between 1957 and 2008 because of the growth of untreated gullies and the establishment of new gullies. Modelling indicates that a larger area than that identified by ECFP or other programmes requires treatment to reduce gully-derived sediment yields, and that despite the area planted to date, gully erosion and sediment yield has increased.

Specific findings are:

- To date, there have been about 54,000 ha (data supplied by MAF – Gisborne office) of forest established in the Waiapu catchment.
- In 2011, the total amount of land planted in the Waiapu catchment under the ECFP was 28,459 ha, of which 46% was target land (R. Hambling, pers. comm.).
- The area of eligible ECFP target land remaining in the Waiapu catchment is estimated to be 13,526 ha (data supplied by MAF – Gisborne office). Planting rates for the next nine years will need to be maintained at the 2011 rate, to achieve

the target of treating all remaining target land by 2020. The 2011 planting rate is 2.5 times greater than the rate in recent years.

- Mature forest can reduce landslide erosion by about 90% compared to unimproved pasture, and well maintained wide-spaced planted trees can reduce the area of slipping by 50-80%. However, partial tree planting and/or poorly maintained wide-spaced planted trees will only reduce erosion by 10-20%.
- For gullies, afforestation of the gully area and the surrounding catchment has been shown to be the most effective treatment. However, trees planted at a spacing of 2-4 m have also been shown to be effective at reducing erosion at 90% of sites.
- The probabilities of stabilising the gullies with afforestation are: >80% for gullies <1 ha in area, ~60% for gullies 1–5 ha in area, 50% for gullies of 5 ha, and little chance of success for gullies >10 ha in area. Linear gullies are more likely to be stabilised than amphitheatre-shaped gullies.
- Analysis of the 1,468 gullies present in the Waiapu catchment in 1957 and of those subsequently planted in exotic forest, a 28% reduction in total gully area was achieved. A 64% reduction in gully area was achieved within one forest rotation (~27 years) in the Waipaoa catchment, where Cretaceous rock types occupy only 8% of the catchment area (Marden et al., 2005). The reduction in gully area over time was attributed to the effects of canopy closure, which occurs within 8-10 years after planting (Marden & Rowan, 1994). A mature closed canopy stand of *Pinus radiata* has the potential to reduce runoff by 25-30%, influencing the hydrology and erosion activity within the gully (Pearce et al., 1987).
- Herzig et al. (2011) and Marden et al. (2011) found that afforestation schemes have been effective at reducing the sediment yield derived from gullies in the Waiapu catchment by approximately 17% from what it would have been without afforestation.
- Although afforestation has been successful in reducing the sediment yield from gullies (c.f. no afforestation), the area of gullies by 2008 had increased by approximately 17% since pre-afforestation (the 1960's) due to the growth of existing gullies, and development of new gullies in gully-prone areas of land that have not been treated (afforested). By 1997, 80% of the gullies in the Waiapu catchment had not been planted, and an additional 850 new gullies were initiated (Marden et al., 2008).
- Marden et al. (2011) estimated that forested gullies contribute 23% of the total gully derived sediment.
- The gully complex model shows that afforestation of ECFP target land is more effective in reducing sediment yield derived from gullies compared to GDC Land

Overlay 3A (LO3A), because ECFP target land incorporates more gullies and involves planting of a greater portion of the catchment surrounding each gully. Planting a larger area surrounding gullies increases infiltration, reduces the amount of runoff reaching gullies, and increases stability around gullies.

- Afforestation is also successful in reducing sediment yields derived from shallow landslides, although we do not currently know the area of land affected by landslides.

4.10 Summary & conclusions

- The geophysical state of the catchment has been described at 1840, 1969, 1988, and 2008 to enable assessment of the size and scale of the erosion problem going forward, and the impacts of past land use changes and efforts and policies to address the erosion problem.
- In 1840, 88% of the catchment was in primary indigenous forest, with the remainder mainly in scrub and secondary forest. In 2008, vegetation cover was as follows: indigenous forest and scrub 35%, planted forest 25%, grassland 35%, and other 5%.
- Gullies, which began to develop following deforestation (1890-1920), now account for 49% of the catchment sediment yield. While the number of gullies has decreased from 1,468 in 1957 to 683 in 2008, sediment yield has risen from 13.49 Mt in 1957 to 23.97 Mt in 2008 due to the increase in size of unplanted gullies and the initiation of new gullies in areas of gully prone land that remain untreated.
- The remaining 51% of the catchment sediment yield is derived from other erosion processes (i.e. landslide, earthflow, sheetwash, streambank erosion, and river bed degradation). The contribution of these processes to the sediment yield is unknown.
- River cross-section data show that while some headwater streams where afforestation has occurred have begun to incise, larger rivers are still aggrading and their channels are continuing to widen.
- While channel incision in response to afforestation has been rapid (decades) in headwater catchments, the rate at which incision will proceed downstream is unknown, and depends on the amount and timing of future afforestation and storm events.
- Afforestation, reversion, and wide-spaced planted trees are all effective in reducing erosion under appropriate conditions.
- The scale of the erosion problem in the catchment can be represented by the area of untreated land with Potential Erosion Severity (PES) of 4 or 5, plus the area of

gully-prone land without effective tree cover that is not included within the area of land with a PES of 4 or 5. This area was estimated to be up to a maximum of about 28,000 ha as at 2008.

- Land with severe potential severity (PES 3) is also likely to require intensive soil conservation measures to prevent significant erosion on this land.
- The gully complex model (Herzig et al., 2011) shows that afforestation has reduced sediment yields by 17% from what it would have been without any afforestation.
- Despite the establishment of 54,000 ha of forest, gully-derived sediment yield has increased by 78% between 1957 and 2008 because of the growth of untreated gullies and the establishment of new gullies.
- The gully complex model suggests that if all gullies were to be afforested by 2020, the sediment yield from gullies could be reduced by half (from 22 Mt/yr to 11 Mt/yr) by 2050, but if afforestation efforts were terminated today, and new gullies were also left untreated, the sediment yield from gullies would double (to 45 Mt/yr) by 2050.
- The gully complex model indicates that a larger area than that identified by the ECFP or other programmes requires treatment to reduce gully-derived sediment yields.
- It is estimated that up to about 28,000 ha of the land remaining under grassland in the Waiapu catchment will need to be treated to attempt to address the erosion problem and reduce sediment yields.
- Natural climate variability, climate change, and the impact of another Cyclone Bola or an earthquake are identified as uncertainties that may affect progress towards the desired state for the catchment.

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5 Erosion, land use, erosion control, & land tenure in the Waiapu catchment

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5.1 Introduction

Erosion in the Waiapu catchment is extreme by world standards, and even by comparison with the rest of New Zealand. The extreme erosion in the Waiapu catchment is caused by:

- Large-scale folding and fault shearing of the underlying rocks and as a consequence, extensive areas of unstable landforms.
- The widespread removal and burning of native forest and scrub between 80 and 100 years ago, and conversion of land cover to short pastures of exotic grass and clover species.
- The high incidence of large magnitude storm events, particularly since forest removal.

The most effective vegetation for controlling erosion, especially on highly erodible land, is closed canopy natural or exotic forest (Basher et al., 2008). A consequence of the change in land cover from natural forest to pasture has been a dramatic increase in both erosion and sediment transfer, indicating that currently, land use driven changes in vegetation override other controls on erosion in the Waiapu catchment (Page et al., 2008).

The huge volume of sediment generated by erosion following deforestation has led to rapid aggradation of the Waiapu River (see Sections 2.9.2 and 4.7). Aggradation in historic times has overwhelmed the background, base-level-controlled incision of the fluvial network (Page et al., 2008). In small headwater tributaries of the Waiapu catchment where afforestation has occurred in the last several decades, channel incision has recommenced in response to the reduction in sediment supply from hillslopes.

However, the nature and rate of channel response in downstream areas are more difficult to forecast, being influenced by the present and future mix and spatial distribution of afforestation, reversion, and soil conservation plantings.

In this chapter, we make a geospatial (map-based) description of current land cover and erosion in the Waiapu catchment to show how much highly-erodible land is in closed-canopy forest and how much remains in pasture. The geospatial description of land cover and soil erosion will then be used to help assess:

- The impact of current land use on erosion in the Waiapu catchment.
- The implications of the erosion problem for land use in the Waiapu catchment.
- How land ownership and government policy – specifically the East Coast Forestry Project (ECFP) and Land Overlay 3A (LO3A) – have influenced the afforestation of the Waiapu catchment since 1969, when the first large-scale efforts to reforest highly-erodible pasture land began.

A description of methodology for the geospatial analyses undertaken is provided followed by the presentation and discussion of results in relation to potential and present erosion severities by land use classes, achievements of the ECFP and LO3A, and erosion (potential and present erosion severities) by land tenure.

5.2 Methodology

5.2.1 Data

The geospatial description and evaluation of policy and current land use was undertaken using existing layers of geospatial data, listed in Table 5.1.

Table 5.1. Summary of geospatial data sources.

Theme	Data Type	Date	Source
Study Area	Waiapu catchment and sub-catchment boundaries	N/A	New Zealand River Environment Classification (REC)
Land use	Land Use Class Land tenure	2008 Current	LUCAS 2008 (version 3) MAF
Erosion	Potential Erosion Severity	1995-1998	NZLRI and LUC (version 2) at 1:50,000 scale
	Present erosion severity	1995-1998	NZLRI and LUC (version 2) at 1:50,000 scale
Current Policy	ECFP target land LO3A land	N/A N/A	MAF GDC

5.2.2 Geospatial analysis

The geospatial analysis was undertaken using a geographical information system (GIS). We have used ArcGIS 10 (ESRI, 380 New York Street, Redlands, CA 92373-8100). The following questions were answered using GIS analysis:

- Where has land that is highly susceptible to erosion been either:
  - maintained in forest, or
  - cleared for pasture but subsequently afforested, or
  - cleared for pasture and is still maintained under pasture?

The underlying susceptibility of land to erosion is identified by the potential erosion severity (PES) layer (Table 5.1), derived from the New Zealand Land Resource Inventory (NZLRI) data for Gisborne and the East Coast region at 1:50,000 scale (Jessen et al., 1999). This can be overlaid on LUCAS 2008 v.3 land cover layers (MfE, 2012) to identify the location and extent of land highly susceptible to erosion under forest (natural forest, scrub, and exotic forest) and pasture vegetation.

Present erosion severity was mapped from 1995-1998 at 1:50,000 scale (Jessen et al., 1999). It can be used as an estimator of the location and severity of sediment sources in the catchment, and when overlain with current land use, will show where current actively eroding land has been afforested, where it has occurred despite the land being retained under natural forest, and where it is occurring on land that is currently maintained under pasture.

A limitation of the present erosion severity and PES maps based on the NZLRI (mapped at 1:50,000 scale) is that they assign erosion severity values to map polygons which range from several hectares to several hundred hectares in size. These maps do not depict specific locations of erosion features. This is important in the Waiapu catchment because individual large erosion features may contribute significant amounts of sediment. The Landcare Research gully erosion studies (Marden et al., 2011) map the location of individual gully features in 1957, 1997, and 2008, and therefore offer a more detailed description of critical sediment sources within the Waiapu catchment.

A limitation of the LUCAS land use map layer is that it does not show where highly erodible land has been treated by means other than blanket afforestation (examples of such alternatives are space-planting of poplars or engineering works). The 'Grassland with woody biomass' land use category in the LUCAS classification (Tables 5.2 and 5.3) will include space-planting poplars, along with areas of scattered reversion to forest or scrub species. Unfortunately, LUCAS does not differentiate between them. Because poplar pole planting will be targeted at specific erosion areas, it is likely to be more effective in combating erosion than scattered reversion of woody species, whose location may not be on the highly eroding part of the landscape.

Current and past programmes to control erosion can be classified as either:

- State-controlled operations (i.e. afforestation by the NZ Forest Service during the period 1969-1991).
- Afforestation by the private sector (including Māori landowners) funded by government soil conservation subsidies (1960‘s to late 1980‘s) and/or the ECFP and other schemes from 1993 onwards.
- Afforestation by the private sector without government subsidy funding.
- Compulsory afforestation mandated by rules in regional plans under the Resource Management Act. The current Gisborne Combined Regional Land and District Plan requires that the most severely eroded land must be forested by landowners. The location of this land is shown by LO3A in the Gisborne Combined Regional Land and District Plan. Landowners can use funds from the ECFP to achieve this.

The impact of these policies can be gauged by the extent of large-scale afforestation or regeneration of natural forest and scrub, or both, from 1969 to 1990, and from 1990 to the present day. The extent and location of this afforestation is shown by the LUCAS land cover geospatial data layers, and also the map layers for established forest planting under the ECFP. GIS analysis of these layers shows what proportion of highly erodible land has been afforested, and therefore the degree of success achieved by the erosion control programmes. In addition; GIS analysis of target ECFP land and LO3A land shows remaining unplanted land within the Waiapu catchment, which is ‘target land‗ for afforestation under these two schemes. The ECFP was reviewed in 1998, and more recently in by Bayfield and Meister (2006).

Implications of the erosion problem for land use in the Waiapu catchment follow from the analysis outlined above. Highly erodible land that is not currently in scrub or forest needs to be afforested to reduce the sediment yield from current erosion features, and to reduce the likelihood of expansion of existing erosion features or the initiation of new ones, or both. However, afforestation of this land will be highly dependent on ownership. Afforestation of freehold land depends on decisions made by individual or corporate owners, but will largely be driven by commercial considerations or mandatory requirements for planting of LO3A land, or both. Afforestation of Māori-owned land will likely be subject to a wider set of considerations, and the decision to reforest will probably involve more complex processes. The overlay of land ownership types with highly erodible land in pasture will depict the likelihood that afforestation will occur, and the rapidity of the decision to commit to afforestation.

It is important note that the results of geospatial analysis are not completely accurate. Small errors occur during the process of overlaying different geospatial data layers within a GIS and producing summaries of land areas falling into different classes or categories of land cover, erosion, etc. However, the errors usually sum to less than 1% of the total area being analysed. For example, in this study, we used a base map for the Waiapu catchment that gave a total catchment area of 173,837 ha. Some of our analyses resulted in areas which added up over the entire catchment to more or less than this figure, but the differences were small (in the order of 1-20 ha) and fall within the range of error that seems to be inherent in GIS analysis. The summation of rounded values for individual components within the tables may also account for some of the minor variance in total area.

5.2.2.1 Land tenure map creation

Land ownership layers for the Waiapu catchment were created in ArcMap10. The data were derived from the Ministry of Agriculture and Forestry (MAF) Māori land ownership dataset, provided by MAF (Malcolm Penn), a catchment boundary dataset (provided by Mark Bloomberg), Land Information New Zealand (LINZ) cadastral datasets (available from www.data.linz.govt.nz/), and a DoC dataset (available from www.koordinates.com). The catchment boundary was used as the definitive area for the Waiapu with all layers generated being matched to this dataset. All land tenure maps created are projected using the NZ Transverse Mercator coordinate system.

The data from the LINZ parcel cadastral layer was clipped to match the catchment boundary using the *clip* tool in ArcMap10. The Māori Title dataset was converted to a point shape file with the *feature to point* tool. Using the *select by location* tool, parcels that contained a point from the Māori Title point file were identified. A new field named *Ownership* was added to the Waiapu parcel layer with the identified parcels labelled *Māori Title*. The above process was repeated for the DoC dataset with identify parcels labelled *DoC Land*. Crown land was identified from the LINZ ownership point dataset tables. Once identified, Crown land points were saved as a new shape file. The *select by location* tool was again used to locate parcels in the Waiapu parcel dataset, with the resulting parcels labelled *Crown Land* in the table. The remaining parcels within the Waiapu catchment without an ownership label were assumed to be owned by private companies and individuals of non-Māori origin. These parcels were given the title of *General Title* in the *Ownership* field.

A layer showing the sub-catchments within the Waiapu catchment was provided by Landcare Research (sub)-sub-catchments (sub-catchment within the sub-catchments) were also created using LINZ topographic maps as a template. The (sub)-sub-catchments were created by digitizing through check points indicted by Mike Page of GNS. The sub-catchment boundaries layer was used in the analysis of the gully dataset undertaken by Landcare Research.

The PES and present erosion severity layers (based on the NZLRI) were overlaid with the land tenure layers to create layers showing both the potential and present erosion severity for each land tenure class. Data from these layers were used to indicate the total area of each erosion category in each land tenure class. The percentage of each erosion category in relationship to each land tenure class was also calculated. Land cover layers for 1969, 1990, and 2008 were also overlaid with the land tenure layers to determine the areas of each land cover (land use) class within each land tenure class (see Appendix 11).

5.3 Results & discussion

5.3.1 Potential erosion severity (PES)

Table 5.2 shows that land with a PES of 4 or 5 makes up about 43% of the Waiapu catchment. Land with a PES of 4 or 5 has very severe or extreme potential for erosion. However, two-thirds of the land with PES of 4 or 5 is already under either natural or planted forest cover, with a small area in grassland with woody biomass. Not all of the remaining area of low-producing grassland with a PES of 4 or 5 is necessarily a present erosion problem, but even the areas not presently seriously eroded have the potential to become so. Figure 5.1 depicts the distribution of PES by each major LUCAS land use class in the Waiapu catchment.

Table 5.2. Potential Erosion Severity (PES) vs. land use class area (2008). All areas are in hectares. Erosion severities are classified as UC-unclassified, 0-nil, 1-slight, 2-moderate, 3-severe, 4-very severe, and 5-extreme.

Land Use	**Potential Erosion Severity**							
	UC	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
Natural Forest	2	815	1,523	8,519	18,399	28,700	2,148	**60,107**
Pre-1990 Planted Forest	0	127	207	4,900	4,629	10,559	24	**20,446**
Post-1989 Planted Forest	0	386	314	6,277	4,684	11,476	149	**23,287**
Grassland with Woody Biomass	2	315	476	1,289	1,295	2,068	38	**5,483**
Grassland High Producing*	1	5,374	4,207	2,966	83	413	0	**13,043**
Grassland Low Producing	23	1,647	1,811	16,365	9,116	18,458	529	**47,950**
Other	33	2,500	343	43	99	353	129	**3,500**
Total	**60**	**11,164**	**8,880**	**40,360**	**38,305**	**72,028**	**3,018**	**173,815**

* Includes Cropland

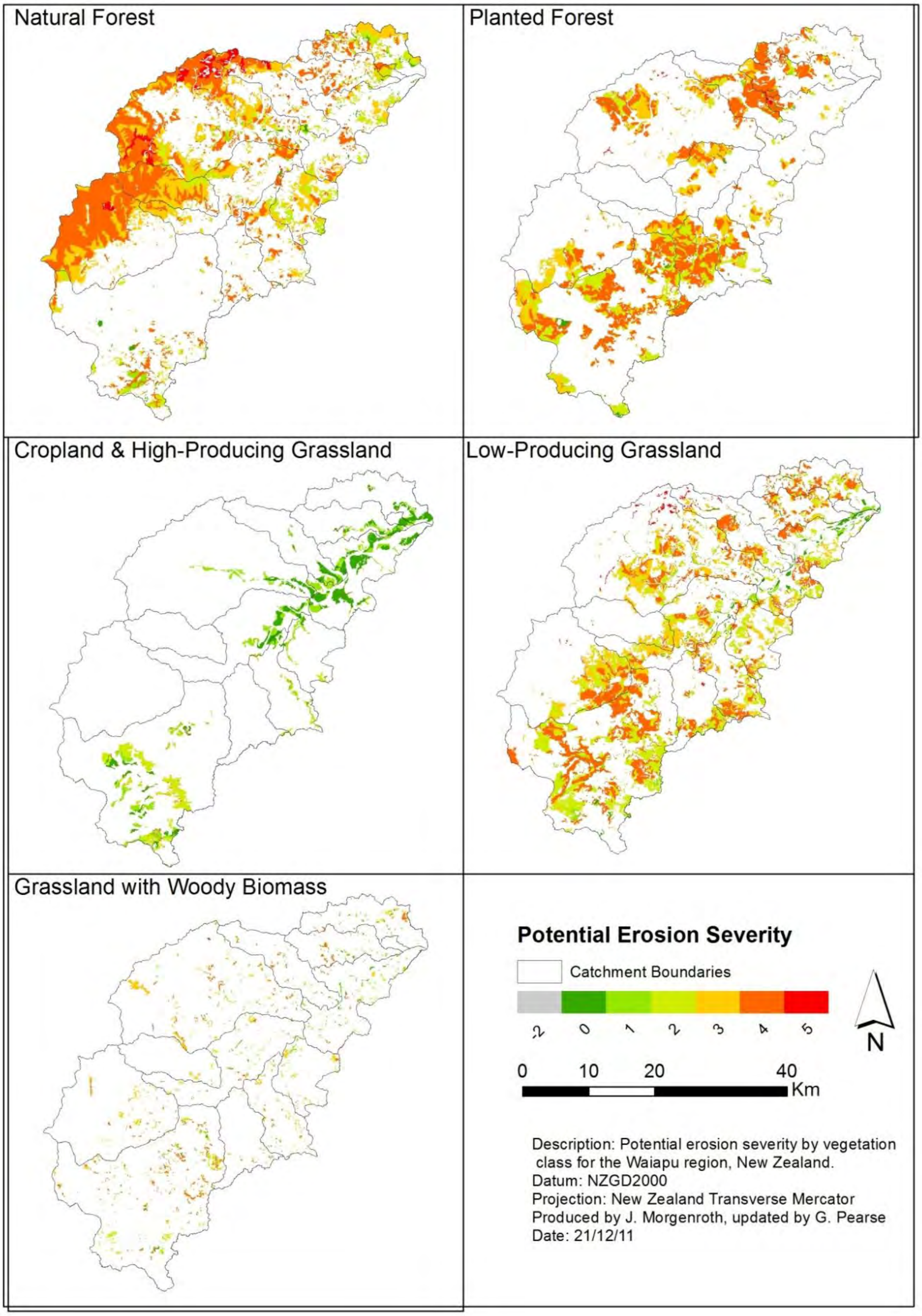

Figure 5.1. Potential Erosion Severity by LUCAS land use classes (as at 2008). Land with potential erosion severities of 4 or 5 have very severe or extreme potential for erosion. ‗Planted Forest' includes all planted forest (pre-1990 and post-1989) that could be detected by the LUCAS programme as at 2008. Some newly established forest may not have been identified.

5.3.2 Present erosion severity

Table 5.3 shows the proportion of land under different *present* erosion severities. This differs from Table 5.2 which identified the *potential* erosion severity of land in the Waiapu catchment. The proportion of land with present erosion severities of 4 or 5 is much lower than the proportion of land with PES of 4 or 5. Eighty five percent of the Waiapu catchment has nil, slight, or moderate present erosion severity, with a further 11% having severe present erosion. Only about 3% of the catchment area has very severe or extreme (4 or 5) present erosion. About seventy three percent of this highly erodible land is under natural or planted forest cover, with only 1,213 ha under low producing pasture cover (Table 5.3 and Figure 5.2). However, note the comment in the previous section that a much larger area of low-producing pasture land has the potential to become very severely or extremely eroded (~19,000 ha).

Table 5.3. Present Erosion Severity (1995-1998) vs. land use class area (2008). All areas are in hectares. Erosion severities are classified as 0-nil, 1-slight, 2-moderate, 3-severe, 4-very severe and 5-extreme.

Land Use	Erosion Severity						
	0	**1**	**2**	**3**	**4**	**5**	**Total**
Natural Forest	5,647	23,704	24,530	5,084	1,116	45	60,127
Pre-1990 Planted Forest	991	9,940	5,637	2,567	1,273	24	20,433
Post-1989 Planted Forest	1,387	8,036	8,033	4,064	1,695	76	23,291
Grassland - Woody biomass	815	2,075	1,781	669	143	2	5,485
Grassland - High Producing*	8,683	3,520	379	87	1	-	12,670
Grassland - Low Producing	4,490	21,447	13,634	7,157	1,142	71	47,941
Other	3,208	189	170	166	90	49	3,871
Total	**25,220**	**68,910**	**54,164**	**19,795**	**5,461**	**267**	**173,817**

* Includes Cropland

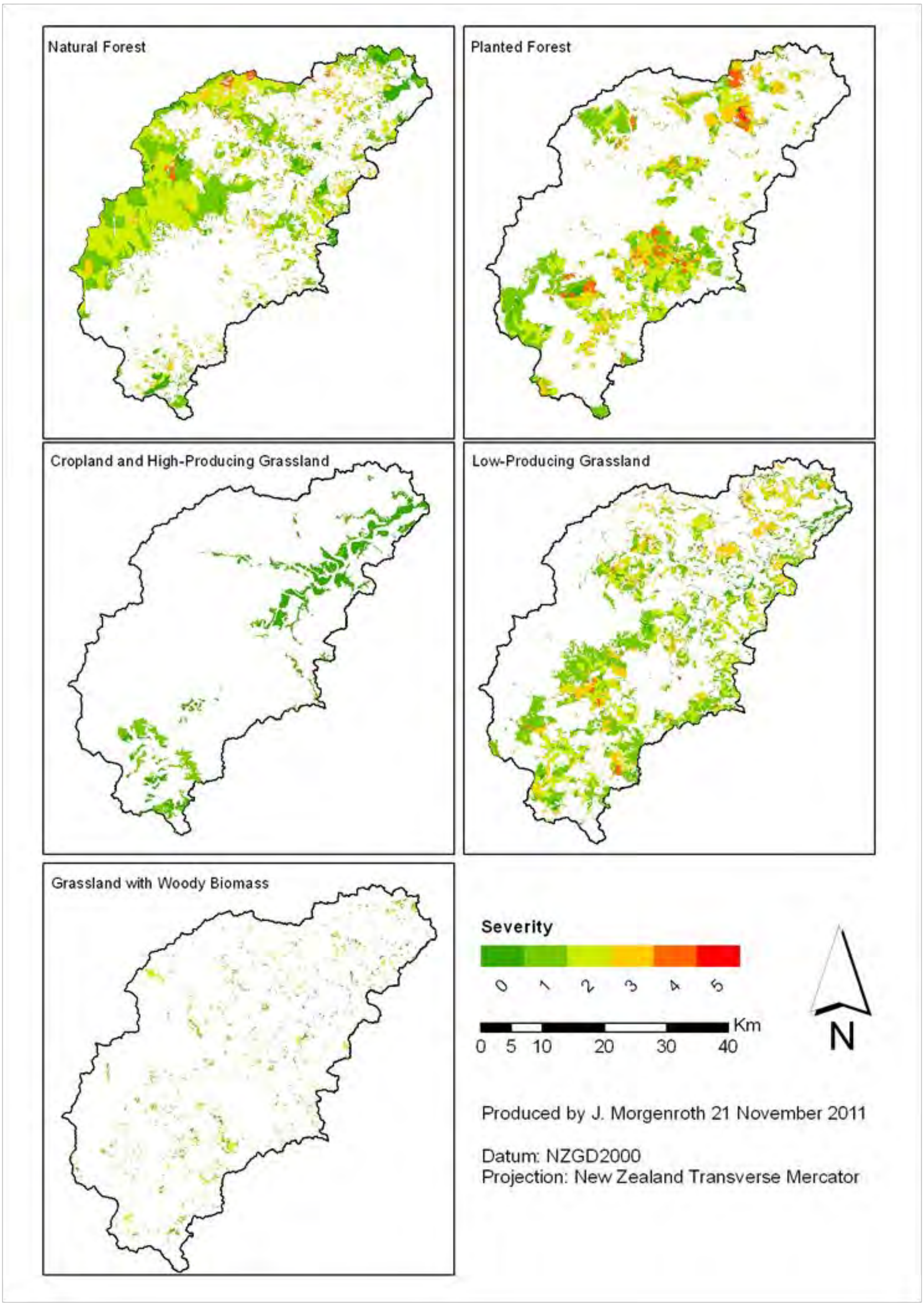

Figure 5.2. Present Erosion Severity (as at 1995-1998) by LUCAS land use classes (as at 2008). Land with present erosion severities of 4 or 5 have very severe or extreme erosion. ‗Planted Forest' is all planted forest (pre-1990 and post-1989) that could be detected by the LUCAS programme as at 2008. Some newly established forest may not have been identified.

5.3.3 Effectiveness of current & past policies to control erosion

Current and past programmes to control erosion include: afforestation by the NZ Forest Service (1969-1991); afforestation by the private sector (including Māori landowners) funded by soil conservation subsidies (1960's to late 1980's) or the ECFP from 1993 onwards; and most recently, compulsory treatment of the LO3A area mandated by rules in the current Gisborne Combined Regional Land and District Plan. The impact of these policies can be gauged by the proportion of highly erodible land that has been afforested, and therefore the degree of success achieved by the erosion control programmes. Both the ECFP and the GDC plan identify their target areas as LUC units 7e18, 19 and 21-25, and 8e2-9. However, the ECFP area is based on the NZ Land Resource Inventory, mapped at 1:50,000 scale. The GDC mapping is based on property-scale mapping, which leads to a smaller area of target land compared with the NZLRI mapping (Bayfield and Meister, 2006). The difference in target area between the ECFP and the GDC LO3A is shown in Figure 5.3. Additional background to the ECFP and LO3A policies and their effectiveness was given in Sections 2.10 and 2.11, respectively.

5.3.3.1 Analysis of ECFP & LO3A achievements

Based on the GIS analysis undertaken in this study, a total of 40% of the ECFP eligible LUC classes in the Waiapu catchment are already in natural forest, leaving 41,003 ha currently under other land covers. Of this 41,003 ha, 22,162 ha (54%) has been planted in exotic forest — either under the ECFP, by the former NZ Forest Service prior to 1991, or by private landowners with or without soil conservation subsidies (Table 5.4). A further 17,271 ha (35% of the target area excluding natural forest) of target land is currently under low producing grassland. The results of our analysis are broadly similar to data supplied by MAF, also shown in Table 5.4, although there is a difference of 3,745 ha in estimated area under low producing grassland (i.e. target land as yet unplanted). The main reasons for this discrepancy are thought to be the additional afforestation within the ECFP target area between 2008 and 2011 and the possibility that some areas afforested just prior to the 2008 LUCAS mapping may not have been recognised as planted forest. However, the difference in area does not alter the conclusion that there is a large area of ECFP-eligible pasture land that is as yet unplanted. For the purposes of this study, we will use the MAF estimate of the area of ECFP target land yet to be treated (i.e. currently under grassland) of 13,526 ha. Note that MAF have indicated that there is uncertainty around their estimate.

Table 5.4. Current land use classes within eligible area for ECFP.

Land Use	GIS Analysis Results (ha)	MAF Data (ha)
ECFP Established	11,352	13,096
Other Planted Forest	10,810	11,262
Natural Forest	26,223	24,975
Grassland with Woody Biomass	1,305	-
Low Producing Grassland*	17,271	14,380†
Other Minor Land Uses	265	-
Total	**67,226**	**63,713**

* In the MAF data, low producing grassland contains grassland with woody biomass, other minor land use classes and also ECFP approved land that is not yet planted.

† Includes 854 ha of DoC land & Queen's Chain which are not eligible for ECFP funding, leaving 13,526 ha of eligible land to be treated based on MAF estimates (R. Hambling, pers. comm.).

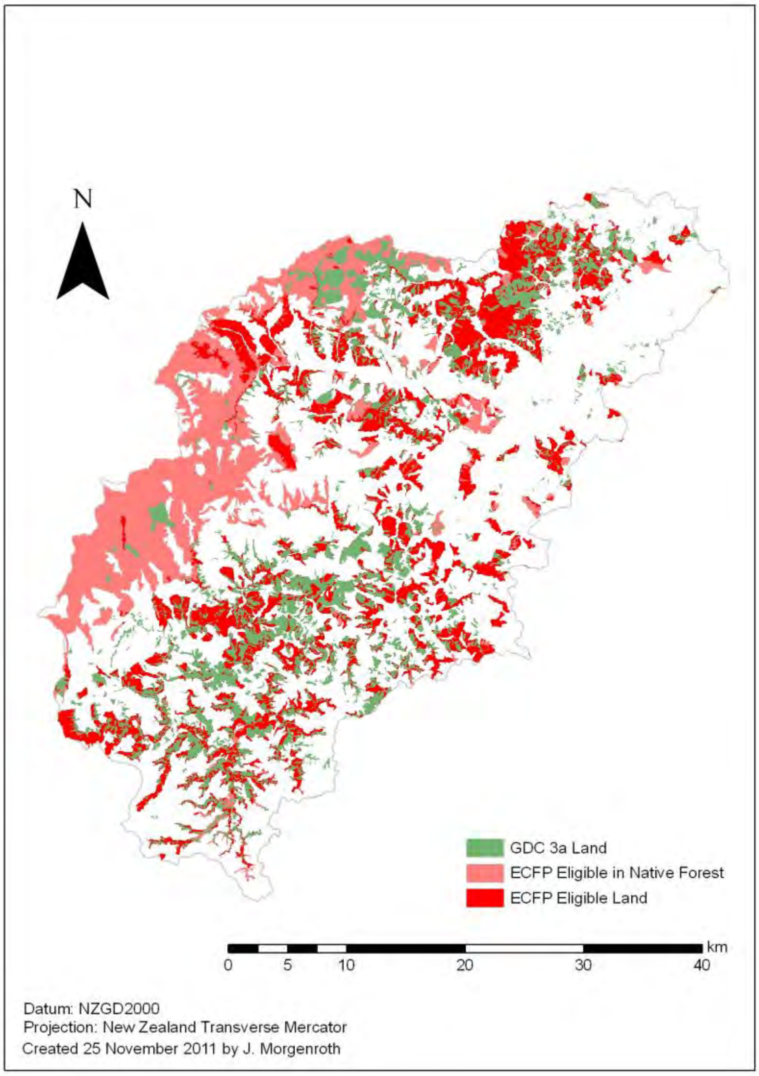

Figure 5.3. Comparison of GDC LO3A land, defined using property-scale LUC mapping vs. ECFP Land, defined using the NZLRI.

The ECFP planted areas also include a significant portion of non-target land, presumably to create forests with practical boundaries, and also to achieve afforestation of relatively stable land surrounding the highly erodible land units. Our GIS analysis shows that 14,466 ha of non-target land have been planted under the ECFP to the end of 2011, which contrasts with a MAF estimate of 15,363 ha.

The GDC LO3A area is about half the size of the eligible ECFP area (with natural forest excluded). LO3A land differs from ECFP target land in that ECFP target land incorporates more gullies and involves planting of a greater portion of the catchment surrounding each gully. Of the LO3A area, 65% is either in planted forest or natural forest (Table 5.5). This leaves 7,770 ha of low producing grassland that GDC require to be treated.

Table 5.5. Current land use classes within the GDC LO3A area (Source: MAF and LUCAS 2008).

Land Use	Area (ha)
All Planted Forest incl. ECFP Established	11,615
Natural Forest	3,679
Grassland with Woody Biomass	509
Low producing grassland	7,770
Other land uses	122
Total	**23,695**

5.3.4 Erosion & land tenure

An analysis of PES by land tenure was undertaken for the Waiapu catchment (Table 5.6). Areas of land cover (land use) classes were also determined by land tenure class for 1960, 1990, and 2008 (Appendix 11).

Table 5.6. Potential Erosion Severity (PES) by land tenure. All areas are in hectares. Erosion severities are classified as UC-Unclassified, 0-nil, 1-slight, 2-moderate, 3-severe, 4-very severe, and 5-extreme.

Land tenure	Potential Erosion Severity						
	0	1	2	3	4	5	Total
Crown Land[†]	537	61	3,757	4,021	9,772	8	**18,156**
DoC Land	113	0	368	6,619	15,188	1,212	**23,500**
Māori Title	7776	224	11,662	14,332	18,623	1,621	**54,238**
General Title	11362	151	24,458	13,338	28,463	176	**77,948**
Total	**19,788**	**436**	**40,245**	**38,310**	**72,046**	**3,017**	**173,842**

[†] Primarily (approximately 96%) former Crown forestry lease land subject to transfer to Ngāti Porou ownership under the Deed of Settlement, with minor inclusions of other Crown land.

About 38% of the highly erodible land (PES 4 or 5) occurs under general title (Table 5.6) and a further 27% of the highly erodible land in is Māori ownership. However, if the area of highly erodible Crown land is added to the area of highly erodible Māori land (much of the Crown land is expected to be returned to Ngāti Porou under the terms of their Treaty settlement with the Crown), the combined area would account for approximately 40% of the highly erodible land. DoC land accounts for about 22% of the highly erodible land within the catchment. The amount of highly erodible land is proportionately highest (relative to other severities) on DoC and Crown land (65 and 54% respectively), reflecting the history of Crown acquisition of highly erodible land for afforestation by the NZ Forest Service. In contrast, the proportion of highly erodible Māori land (27%) is less than the overall proportion of highly erodible land in the Waiapu catchment (43%). However, Māori and DoC own most of the PES 5 land (extreme potential erosion severity). The spatial distribution of PES by land tenure is shown in Figure 5.4. The maps show that much of the DoC land has a PES of 4 whereas the land under Māori and general titles has more of a mixture of potential erosion severities.

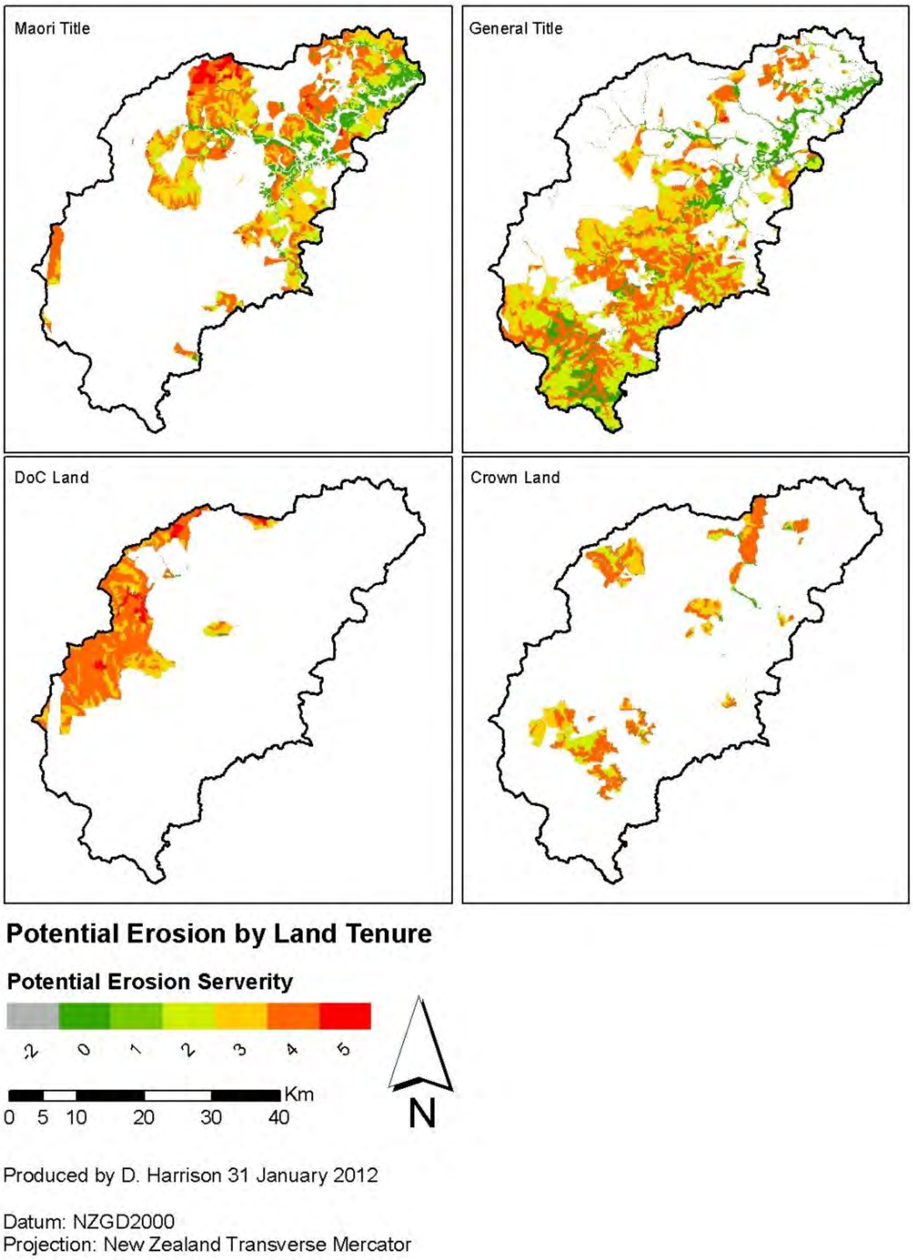

Figure 5.4. Potential Erosion Severity (PES) by land tenure.

Present erosion severity by land tenure was also examined (Table 5.7). A small proportion of the land within the catchment has a present erosion severity of 5 but where this land does occur, a little over half occurs on Māori land with much of the remainder on land under general title. About 34% of the land with present erosion severities of 4 or 5 occurs under general title (Table 5.7) whereas 38% of the land with present erosion severities of 4 or 5 is in Māori ownership. Maori and Crown land combined account for about 60% of the land with present erosion severities of 4 or 5 within the catchment. In contrast, only 6% of the land with present erosion severities of 4 or 5 occurs under DoC ownership. As with potential erosion severity, a relatively high proportion of the Crown land has present erosion severity of 4 or 5 — about 7% of Crown land is has a present erosion severity of 4 or 5 whereas about 4% of Māori land has a present erosion severity of 4 or 5. In contrast, DoC land has a much lower proportion of land with a present erosion severity of 4 or 5 (1.5%) compared to the proportion of DoC land with a PES of 4 or 5 (65%). This difference probably reflects the protective role of the forest vegetation cover on the DoC land.

Table 5.7. Present Erosion Severity by land tenure. All areas are in hectares. Erosion severities are classified as 0-nil, 1-slight, 2-moderate, 3-severe, 4-very severe, and 5-extreme.

Land tenure	**Present Erosion Severity**						
	0	**1**	**2**	**3**	**4**	**5**	**Total**
Crown Land†	1,137	8,290	5,089	2,353	1,280	7	**18,156**
DoC Land	676	7,886	13,785	805	346	0	**23,498**
Māori Title	11,023	18,814	14,525	7,714	2,013	150	**54,239**
General Title	12,408	33,917	20,771	8,919	1,822	111	**77,948**
Total	**25,244**	**68,907**	**54,170**	**19,791**	**5,461**	**268**	**173,841**

† Primarily (approximately 96%) former Crown forestry lease land subject to transfer to Ngāti Porou ownership under the Deed of Settlement with minor inclusions of other Crown land.

The spatial distribution of present erosion severity by land tenure is shown in Figure 5.5.

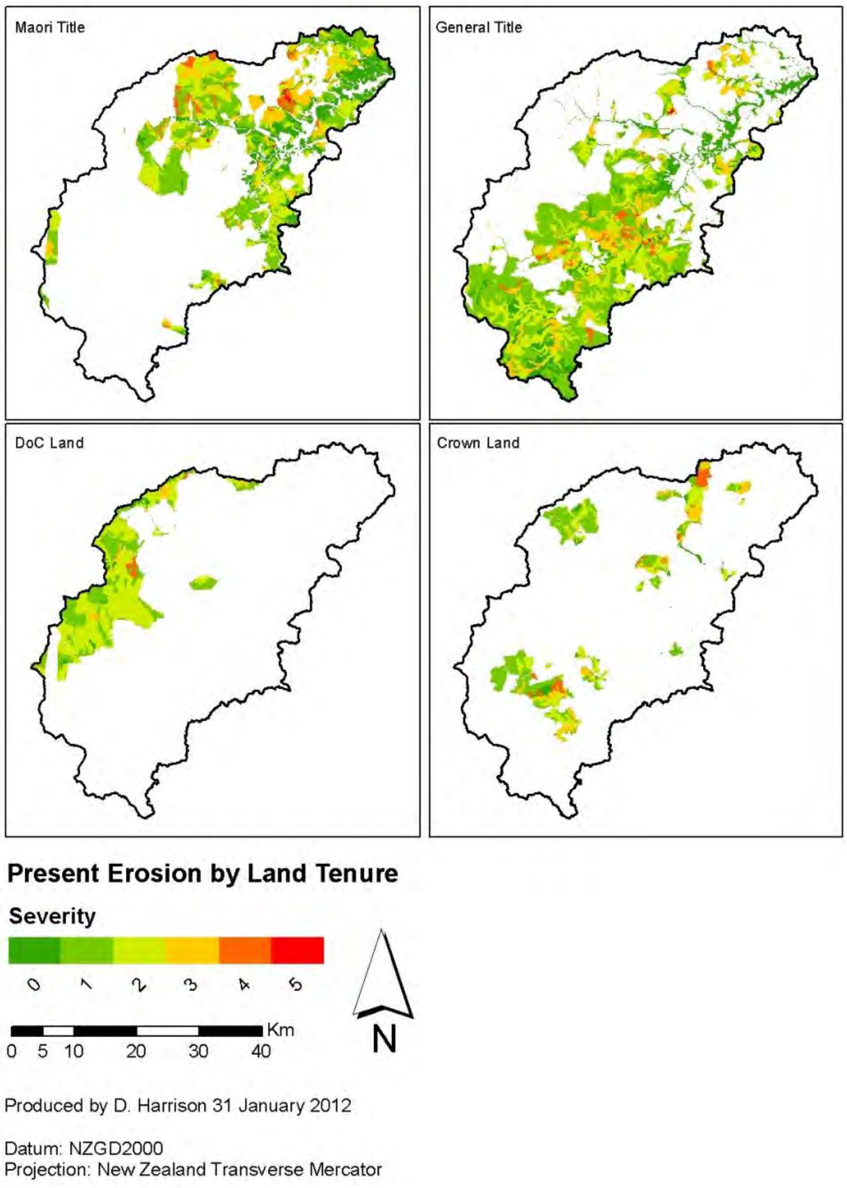

Figure 5.5. Present Erosion Severity by land tenure.

5.4 Summary & conclusions

- This chapter includes a geospatial (map-based) description of current land cover, land tenure, and erosion in the Waiapu catchment, and uses this to gauge the effectiveness of policies intended to control erosion.
- The effectiveness of policies to control erosion can be gauged by the extent of large-scale afforestation or regeneration of natural forest and scrub from 1969 to the present day. In addition, geospatial analysis of target ECFP land and LO3A land shows remaining unplanted 'target land_for afforestation.

- Highly erodible land with a potential erosion severity (PES) of 4 or 5 makes up 43% of the Waiapu catchment. However, about two-thirds of the land with PES of 4 or 5 is already under natural or planted forest cover, with a small area in grassland with woody biomass. About 19,000 ha remain in pasture, and are therefore at risk of very severe or extreme erosion.
- Only about 3% of the catchment area has very severe or extreme (4 or 5) present erosion and three quarters of this land is under natural or planted forest cover.
- Both the ECFP and GDC's Combined Regional Land and District Plan identify their target areas as LUC units 7e18, 19 and 21-25, and 8e2-9. However, the ECFP area is based on the NZ Land Resource Inventory, mapped at 1:50,000 scale. The GDC mapping is based on property-scale mapping (for reasons of enforcement and farm plan development), which leads to a smaller area of target land compared with the NZLRI mapping.
- Based on the analysis undertaken in this study, a total of 40% of the ECFP eligible LUC classes in the Waiapu catchment are already in natural forest, leaving 41,003 ha currently under other land covers. Of this 22,162 ha have been planted in exotic forest. Data supplied by MAF indicate that there are about 13,526 ha of ECFP target land yet to be treated (i.e. currently under grassland). Areas planted under the ECFP also include a significant portion of non-target land (14,466 ha).
- The GDC LO3A area is about half the size of the eligible ECFP area (with natural forest excluded). LO3A land differs from ECFP target land in that ECFP target land incorporates more gullies and involves planting of a greater portion of the catchment surrounding each gully. About 65% percent is either in planted forest or natural forest. This leaves 7,770 ha of grassland that GDC require to be treated.
- About 38% of the highly erodible land (PES 4 or 5) occurs under general title and a further 27% of the highly erodible land in is Māori ownership. However, much of the Crown land area is expected to be returned to Ngāti Porou under the terms of their Treaty settlement with the Crown. Combined Crown and Māori land would account for approximately 40% of the highly erodible land. DoC land accounts for about 22% of the highly erodible land within the catchment.
- Afforestation of general title land will largely be driven by commercial considerations or mandatory requirements for planting of LO3A land, or both. The uptake of treatment on privately-owned land will be voluntary except in areas where it is required under the Gisborne Combined Regional Land and District Plan (i.e. LO3A). Afforestation of Māori-owned land will likely be subject to a wider set of considerations, and the decision to reforest will probably involve more complex processes.

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6 Benchmarking, scope assessment, & critical evaluation – social, cultural, & economic aspects of erosion for Ngāti Porou & a desired state for the Waiapu catchment

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6.1 Introduction

This chapter combines descriptions of the states of the catchment, scope and scale of the issues concerned and an evaluation of current efforts to address the problem from a Ngāti Porou perspective using a bi-cultural framework of indicators developed by members of the community during a series of hui. These indicators relate directly and indirectly to erosion and are drawn from a more comprehensive list that reflects understandings of what constitutes the wellbeing of Ngāti Porou in the Waiapu catchment.

6.1.1 A Ngāti Porou worldview

When considering this research, it is necessary to understand the holistic world view that is fundamental to Ngāti Porou. This intimate relationship between the people of Ngāti Porou and the natural world is best represented in the pepeha that is central to the identity of the Iwi.

Ko Hikurangi te Maunga
Ko Waiapu te Awa
Ko Ngāti Porou te Iwi
Hikurangi is the Mountain
Waiapu is the River
Ngāti Porou is the Tribe

Ngāti Porou and its people are joined to the natural environment through whakapapa, tikanga and kawa. Together, these provide a cultural framework passed down from successive generations. This connection is demonstrated through whaikorero, cultural norms, matauranga, reo and art.

> *"The thing about the Waiapu and rivers like it, is that it is a cultural icon on the landscape. It is your cultural framework. Everywhere you go our men stand up and talk about ko Waiapu te Awa, it's the starting point for a lot of the orators."* (Maro, pers.comm.).

Based on the findings of the literature review (p137) and research accompanying this report, the connection between the environment and the economic, social, and cultural wellbeing of the people is vitally important for Ngāti Porou. The health of the river and the health of the people are one and the same.

6.1.2 A brief summary of events that have shaped the Waiapu catchment

There are two time periods that have major significance to understanding and interpreting the context of a desired state for the catchment. They include: the period prior to major forest clearance (up to 1880) in which the health of the catchment was deemed to be functional and able to support a relatively large population with a wide range of resources; and the present state. Various social, economic and environmental events and processes over the last 130 years have transformed the community and the land. In general, it is believed that both the wellbeing of the river and the people has declined as result and for Ngāti Porou they are inextricably linked.

Prior to major European settlement, the Waiapu catchment appears to have been well populated with local people enjoying a high standard of living compared with other regions of New Zealand (Rau, 1993, p3). The river and its tributaries, the forest and the coast provided food and other resources that appear to have supported a healthy and relatively large population. Like elsewhere in the East Coast region, Ngāti Porou in the Waiapu lived in large villages and marae along valleys and streams and on the coast itself (Beckwith, 2007). The relative isolation of the catchment, its surrounding mountains and dense forests also offered protection and security (Rau, 1993). Forest clearances from 1880 to the late 1930's would transform the physical environment and the social, cultural and economic characteristics of the region. Earliest census data available for the Waiapu is shown below in Table 6.1 and emphasises both the effects of isolation of the catchment and importance of the area to Ngāti Porou.

Table 6.1: An overview of social, cultural, and economic characteristics of the catchment prior to major European settlement (pre- 1870).

Resource/ characteristic	Description of the catchment
Settlement and demographics	Archaeological evidence suggests Māori settlement was widespread in the catchment. One hundred archaeological sites have been recorded including pā, pits, terraces, agricultural field systems and middens (Leahy and Walsh, 1979 described in Beckwith, 2007). Settlement was quite intensive on both sides of the Waiapu River Mouth with the river itself serving as the main artery of communication. While these archaeological sites were dispersed, the highest density appears to be found on the south bank of the estuary mouth (Beckwith, 2007). Papa kainga, with associated maara, housing and outhouses would have been placed close to food and water resources. The location of many of these sites is now lost (Harmsworth et al., 2002). Population levels are uncertain however prior to 1840; there were an estimated 3000 inhabitants at Whakawhitira Pa (Harmsworth et al., 2002). Under times of threat, the people of the Waiapu Valley would have been able to draw on a force of 3000 warriors (Rau, 1993).
Food resources	Land use activity in the takiwa was based along traditional lines of providing food for the community and incorporated the concept kaitiekitanga - the people acting as guardians or stewards of the environment: • Nga ika wai Māori – the Waiapu and its tributaries provided a range of freshwater fish and other food resources (Harmsworth et al., 2002). • Kai Moana – the Waiapu estuary contained shellfish and a range of sea fish (Harmsworth et al., 2002). • Kai Ngahere – surrounding forests offered food resources including birds, bats and a range of plants and berries (Harmsworth et al., 2002). Between 80-90% of the native forest cover was thought to be intact in 1840 (Harmsworth et al., 2002). • Maara – the Waiapu Valley was an ideal area to settle due to the fertile land and abundance of food from the cultivation of kumara and taro (Beckwith, 2007).
Rongoa	Forest plants and trees provided resources for medicines and other uses (Harmsworth et al., 2002).
Other river resources	In addition to food, the Waiapu and its tributaries offered water resources for a number of purposes including drinking, washing and bathing. Successful and continued settlement in the catchment would have been dependent on water and its health (mauri, ora, orange) (Harmsworth et al., 2002). Flax was recorded as being harvested and exported in the late 18th century (Harmsworth et al., 2002).

Between 1880 and the early 1890s farming activity was limited in the catchment – especially in the hill country. Some crops were grown and traded outside the valley including: wheat, corn potatoes, kumara, sheep, pigs, horses. Areas being actively farmed were close to the beach or in areas formerly cleared by Māori (Harmsworth et al., 2002). Farming in the Waiapu in 1891 appears to have been relatively prosperous compared with the rest of New Zealand. The area of crops sown by Ngāti Porou in the county (6,092 acres) was equivalent to 8% of the total crops sown by Māori in the whole of New Zealand. The number of livestock held (25 498) was 6.5% of the New Zealand total for Māori, mainly comprising of sheep, followed by pigs, then cattle (Statistics New Zealand, 1891). According to the 1891 census, the Waiapu County was dominantly Māori, 100% Ngāti Porou, which was different when compared to the remaining of New Zealand (Figure 6.1 and 6.2). Of all people identified as Ngāti Porou 60% were present within the Waiapu County (Figure 6.3).

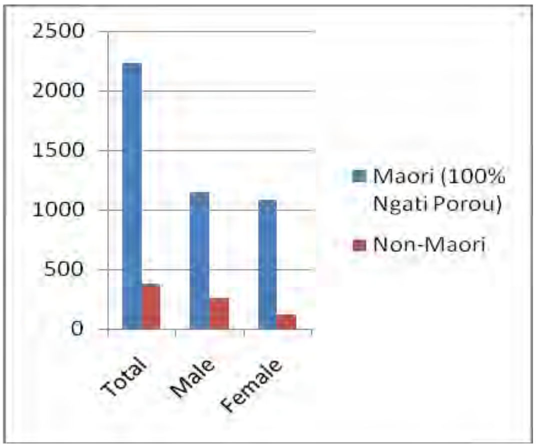

Figure 6.1: 1891 Waiapu County population.

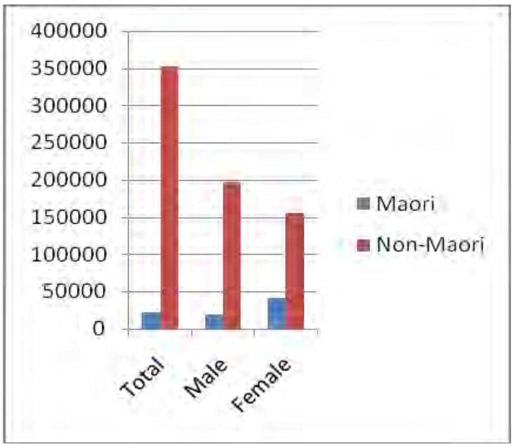

Figure 6.2: 1891 New Zealand population.

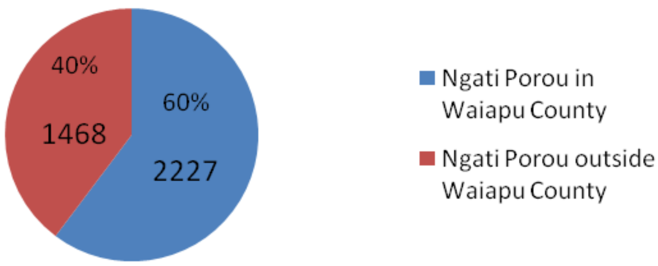

Figure 6.3: Population of Ngāti Porou in Waiapu County 1891.

Between 1891 and 1920, bush clearances accelerated and pushed inland and down the slopes of the hill country with fires used to clear felled forests. These bush burns added to the fertility of soils in the short term, with land-use being dominated by sheep and beef farming. Many Māori were involved in the felling and built homes using the timber. Native trees being harvested included totara, matai, and rimu (Harmsworth et al., 2002).

In 1938, a major cyclonic event hit the Waiapu catchment, with 762 mm of rain falling within 30 hours. Extensive erosion of the hill country led the Waiapu County Council to advocate tree planting and stream control. The significance of this event may not have been fully appreciated by the Waiapu community at the time (Rau, 1993) with most farmers regarding the event as a one-in-a-hundred year event (Harmsworth et al., 2002). The process of healing the scars of the 1938 storm continued for several years.

Between 1940 and 1970, multiple land ownership meant that Ngāti Porou had difficulty in obtaining finance to develop their land or rehabilitate farms, the result being scrub reversion on unmanaged land. In addition, leased land was being returned to Māori in a degraded state (Harmsworth et al., 2002).

The 1950‘s, 1960‘s and 1970‘s saw a period of rural depopulation (Harmsworth et al., 2002) which may have reflected an endemic rural trend in New Zealand in the late 20th Century (Fairweather et al., 2000). The development of plantation forestry in the catchment gained momentum in the late 1960‘s. Considerable debate and conflict arose over the impacts of afforestation on the community and fears were expressed over the future of farming in the region (Harmsworth et al., 2002). Debate over the social and economic merits of afforestation on East Coast has been the subject of numerous reports and studies. Fairweather et al. (2000) revealed that forestry and agriculture on the East Coast appeared to employ fewer people than elsewhere in the country. A more detailed analysis of socio-economic indicators revealed a decline in wellbeing from 1986-1996 for both farming and forestry areas, but that it was most marked with forestry. They went on to comment that rural communities that witnessed large scale conversion to forestry (and which did not possess a wood processing capability) were most likely to experience the ‗most negative‘ effects of change, notably a decrease in family based farms and the emigration of younger people.

Afforestation increased throughout the 1970‘s with the New Zealand Forest Service buying and planting up significant areas of land in the East Cape region. In 1969, the ‗worst land in the Waiapu catchment‘ was identified by Government with no local engagement. As afforestation gained momentum in the catchment so did the ferocity of opposition (Harmsworth et al., 2002). A period of socio-economic decline continued into the 1970‘s (Rau, 1993). Plans to redevelop Ruatoria sparked a brief period of optimism at the beginning of the 1980‘s but that was halted by the disestablishment of the forest service, forest sales and abolition of tax incentives for forest planting (Rau, 1993). The destruction of the Tikitiki vineyards heightened local mistrust of Government (Rau, 1993). The region suffered from periodic outbreaks of serious crime and unrest which further destabilised a community already reeling from economic decline.

A series of major weather events punctuated the 1980's. A Christmas flood in 1980 and Cyclone Bernie 1982 resulted in significant damage to land and property. Droughts in 1983 and 1986 threatened the newly established plantations. A major weather event in 1988, Cyclone Bola, left the region devastated. The community was in shock, damage to the Waiapu County was estimated at $10 million (Harmsworth et al., 2002) and the full impacts of the storm were written into the landscape and the psyche of the people. Following Bola, forestry seemed to have become more accepted as part of the restoration of the catchment and increased through the establishment of Nāgti Porou Whanui Forests Limited, the East Coast Forestry Project and the inclusion of Crown Forestry Leases in the Ngāti Porou 2011 Treaty Settlement.

The 1990's to present day, has seen a revitalisation of Ngāti Porou identity. A series of initiatives by Ngāti Porou have attempted to tackle the legacy socio-economic decline and land degradation. Examples include Pou Ariki Trust, Ngāti Porou Hauroa, and Ngāti Porou Seafoods.

6.1.3 Some Ngāti Porou perspectives on the legacy of erosion and land-use change in the catchment

Interviews held with kaumatua during this research paint a picture of mamae over the current state of the Waiapu River and catchment. A sense of hopelessness was expressed discussing that the real damage to the Waiapu happened many years ago, before many of their times. There is a clear feeling of sadness that due to inappropriate land and water management there has been degradation over the last 100 years for the Waiapu. The following quotations reflect Ngāti Porou views on the legacy of land use change in the catchment.

For many Māori, the clearances of native forest are viewed with deep regret:

> *"A lot of bush they had burnt down, they didn't even bother to take the best trees out; they just burned everything just to get rid of the trees and fence it off and put stock there." (Harmsworth et al., 2002, p48).*

Clear links have been made between the felling of native bush, subsequent flood events and the impacts of erosion:

“Our place has been subject to floods for generations ever since they cleared the back country.” (Harmsworth et al., 2002, p48).

“When the trees were cut, the land began to move; there those ones that had the most slips. Waingakia, Mata, Ihungia and Tapuwaeroa. That place is filled with rocks from the slips. It is the same with the Waiapu – it has been filled in. The stations there have all gone; there are blocks of land that are there in the Waiapu.” (Harmsworth et al., 2002, p48).

Restoration of the balance between people and the land is viewed by some as essential if the catchment is once again to support the community:

“It’s just been take, take, take, and there’s been no give. And when there’s no give, that’s what happened with mother earth. That’s the only way she can say, Hey, enough’s enough. You know erosion, the floods – the kai is disappearing.” (Harmsworth et al., 2002, p49).

“We want clean water for starters. We want all our tuna and kai back in our waters. We want to be able to swim in it without catching, whatever these things are… Giardia.” (Collier, pers. comm. 2011).

“We haven’t got clean water, it is totally unsafe and sadly the Kahawai have seemed to have packed up and left.” (Kaa, pers. comm. 2011).

There is also recognition of the scale of impact of erosion on the community and that the process of recovery is going to take many years:

“There is a whole lot of land disappeared out there. We haven’t yet reached the final destruction of the Waiapu. It started way back. It doesn’t matter what we do on this side of the bridge. We can’t stop anything that is already created, it’s going to take another 100 years.” (Maro, pers. comm. 2011).

6.2 Methods

6.2.1 Literature review and the development of indicators for evaluation of efforts

The method described employs a bi-cultural approach to the consideration of the effects of erosion on Ngāti Porou. A review of literature was undertaken capturing the major ethnographic studies undertaken in the East Coast with reference to Ngāti Porou and the Waiapu catchment, on the direct and indirect social, cultural and economic dimensions of erosion and land use change. The review was presented as a kōrero within an aspirational 10 point framework developed by Te Haeata, the sub-committee responsible for the supervision of the Ngāti Porou Treaty of Waitangi Settlement Negotiations with the Crown (Te Haeata reports to Te Runanga O Ngāti Porou Board of Trustees). The aspirational framework was developed through three Ngāti Porou Wananga held in February and March 2009 to identify a prioritised set of issues that are key to achieving Ngāti Porou aspirations and vision. Te Haeata described ten aspirations for Ngāti Porou as follows:

- Strong identity – whakapapa,
- Ngāti Poroutanga,
- Employment & wealth creation (economic),
- Te Reo & tikanga,
- Whanau,
- Mana Motuhake,
- Connectedness,
- Matauranga,
- Clean environment, and
- Infrastructure.

Erosion will have an impact, either directly or indirectly, on most of these expressed aspirations. Using the aspirational framework the literature review will then capture a baseline of existing knowledge that may then be used to aid in the description of an aspirational (desired) state for the catchment and its people, with a focus on erosion.

A wananga process with Ngāti Porou was undertaken, and informed by the findings from the literature review, to develop a set of draft indicators with the Ngāti Porou Consultative Group via a series of hui. Following subsequent iterations, a final set of criteria and indicators was developed. This set of indicators that may be used to assess the wellbeing of Ngāti Porou and their relationship to issues associated with erosion through a description and measure of the progress toward a ‗desired' state and to evaluate current efforts. The indicator set is only interim and further consultation with the broader Ngāti Porou community in the Waiapu will be required if they are to be used more extensively.

6.2.2 Size and scope assessment

The assessment of the size and scope of the erosion issue draws on the complete body of research contained within this report. The analysis is based around key effects of erosion on biophysical functions, as derived from the Food and Agriculture Organisation and elaborated by Dominati et al (2010), and the categorization of human social impacts as proposed by Vanclay (2002). Indicative comments on the nature of the economic aspects of erosion are also included where data is readily available.

6.2.3 Socio-economic analysis

6.2.3.1 Sources of data

The main source of data on the socio-economic circumstances of the people of the Waiapu catchment and related districts is the 5-yearly New Zealand Censes of Population and Dwellings. The collection and presentation of census data is organised according to territorial local authority (council and ward), township/suburb, and neighbourhood. In rural areas, census neighbourhoods (i.e. meshblocks) are based on both geophysical and social features, such as rivers, roads, or edges of a residential area. Administrative boundaries typically follow census boundaries. See Appendix 7 for Details of the census meshblocks in the Waiapu catchment (using the 2001 Statistics New Zealand map-base) and Appendix 8 for meshblock boundaries.

In census parlance, a *census area unit* typically equates to a suburb in the city, a provincial township (e.g. Ruatoria), or a rural district, while *a census meshblock* equates to a neighbourhood, and is the smallest area for which census data is made available by Statistics New Zealand (SNZ). Over time, SNZ and its predecessors have tried to maintain consistent geographical boundaries for the census to allow for time-series comparisons while accommodating changes in local government boundaries and growth in townships etc. Hence, in the Gisborne District, the boundaries of the former Waiapu County Council are maintained as the East Cape and Ruatoria area units.

6.2.3.2 Catchment and census boundaries

Figure 6.4 shows the catchment boundaries overlaid onto the current area unit boundaries. As can be seen, the catchment falls substantially within the East Cape and Ruatoria area units, and within the former Waiapu County Council area.

Figure 6.4: The Waiapu catchment overlaid onto the Census Area Unit boundaries.

6.3 Socio-economic profile of the Waiapu catchment

6.3.1 Population

At the time of the 2006 census, there were approximately 2304 people residing in 723 households within the Waiapu catchment area and of these 756 (or 33%) of the population lived in Ruatoria. Across the whole East Cape area there were 2751 people, the catchment therefore accounts for the majority of the East Cape population. In 1996, the population of the Waiapu catchment was approximately 2,694. While the national population has increased by over 20% over the past 25 years, the resident population of the East Cape area has shrunk significantly (Figure 6.5), over the same time period, the Gisborne District population has been relatively static. The average household size across the catchment was approximately 3.2 persons, which is large by national standards.

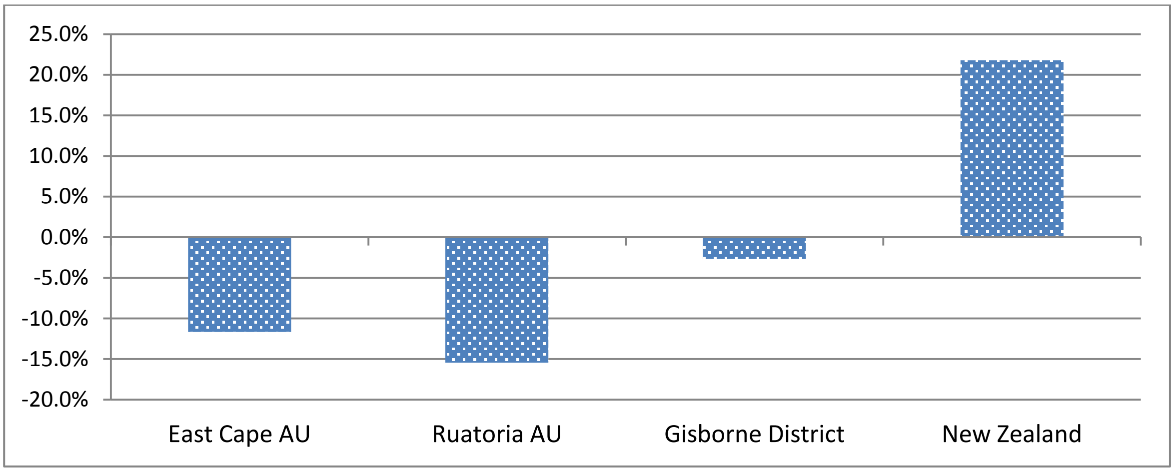

Figure 6.5: Change in East Coast resident population 1986-2006.

At the time of the 1986 census, there were approximately 2775 people resident within the Waiapu catchment, approximately 600 more than in 2006. Data for Waiapu County shows that the population had been growing slowly through the 1980s until 1986, when it began to fall. In 1986, some neighbourhoods in the catchment had more than twice the population than recorded in 2006.

6.3.2 Ethnic composition

In the 2006 census, approximately 1,458 people in the Waiapu catchment were listed as of Māori ethnicity (i.e. 63% compared with 47% for all of Gisborne district), and 1713 said they were of ‗Māori descent' (i.e. 74%). Some of the catchment's meshblocks are almost exclusively Māori. The study area therefore has one of the highest relative concentrations of Māori in New Zealand.

In 1986, 2274 (or 82%) of the catchment residents themselves as of Māori ethnicity or descent, and 16% were ‗European only'.

6.3.3 Age composition

Due to Statistics New Zealand confidentiality restrictions on release of data for small areas, the 2006 meshblock data do not allow for accurate calculation depiction of the age structure of the Waiapu catchment population. Nevertheless, the dependency ratios[1] for the East Cape and Ruatoria area units indicate well above average dependency (i.e. 0.64 and 0.66 dependents per adult compared with 0.51 for the nation). This reflects the comparatively high number of children in the East Cape area. Likewise, the median ages for these areas (34 and 29, respectively) are lower than for the nation's population.

6.3.4 Socio-economic deprivation

In New Zealand, the Index of Deprivation is used to summarise the relative socio-economic conditions in an area, and thus help target intervention programmes and policies. The index combines a selection of key variables from the Census of Population and Dwellings (see Table 6.2), and takes the form of a decile rating for a census meshblock, and for an area unit, an average score for the meshblocks in that area unit. The index score ranges in value from 1 to 10, with ―10" meaning the area is within the most deprived 10% (lowest decile). The deprivation scores derived from the 9 component variables are also available. These scores are adjusted to have a mean of 1000 and a standard deviation of 100. The most recent version of the Index is NZDep2006 (Salmond et al., 2007) and is constructed from the variables listed in Table 6.2.

[1] The number of those in dependent age groups divided by the remainder.

Table 6.2: The Components of the NZ Index of Deprivation (from Salmon et al., 2007).

Dimension of Deprivation	Variable – in order of decreasing weight
Income	People aged 18-64 receiving a means tested benefit.
Income	People living in equivalised* households with income below an income threshold.
Home ownership	People not living in their own home.
Support	People aged <65 living in a single parent family.
Employment	People aged 18-64 unemployed and seeking work.
Qualifications	People aged 18-64 without any educational qualifications.
Living space	People living in equivalised* households below a bedroom occupancy threshold.
Communication	People with no access to a telephone.
Transport	People with no access to a car.

* Equivalisation: methods used to control for (or standardise) household composition.

According to the 2006 Deprivation Index, the East Cape area (and Gisborne District) is one of the most socio-economically deprived areas in the country (see Figure 6.6). This has been the case since deprivation indices were attempted in the 1980s. Within the District, the people of Waiapu catchment especially those resident in the northern part (i.e. lower end of the river) are among the 10% most deprived people in the nation. In short, the residents of the Waiapu catchment are especially poor by New Zealand standards both materially and in access to opportunity.

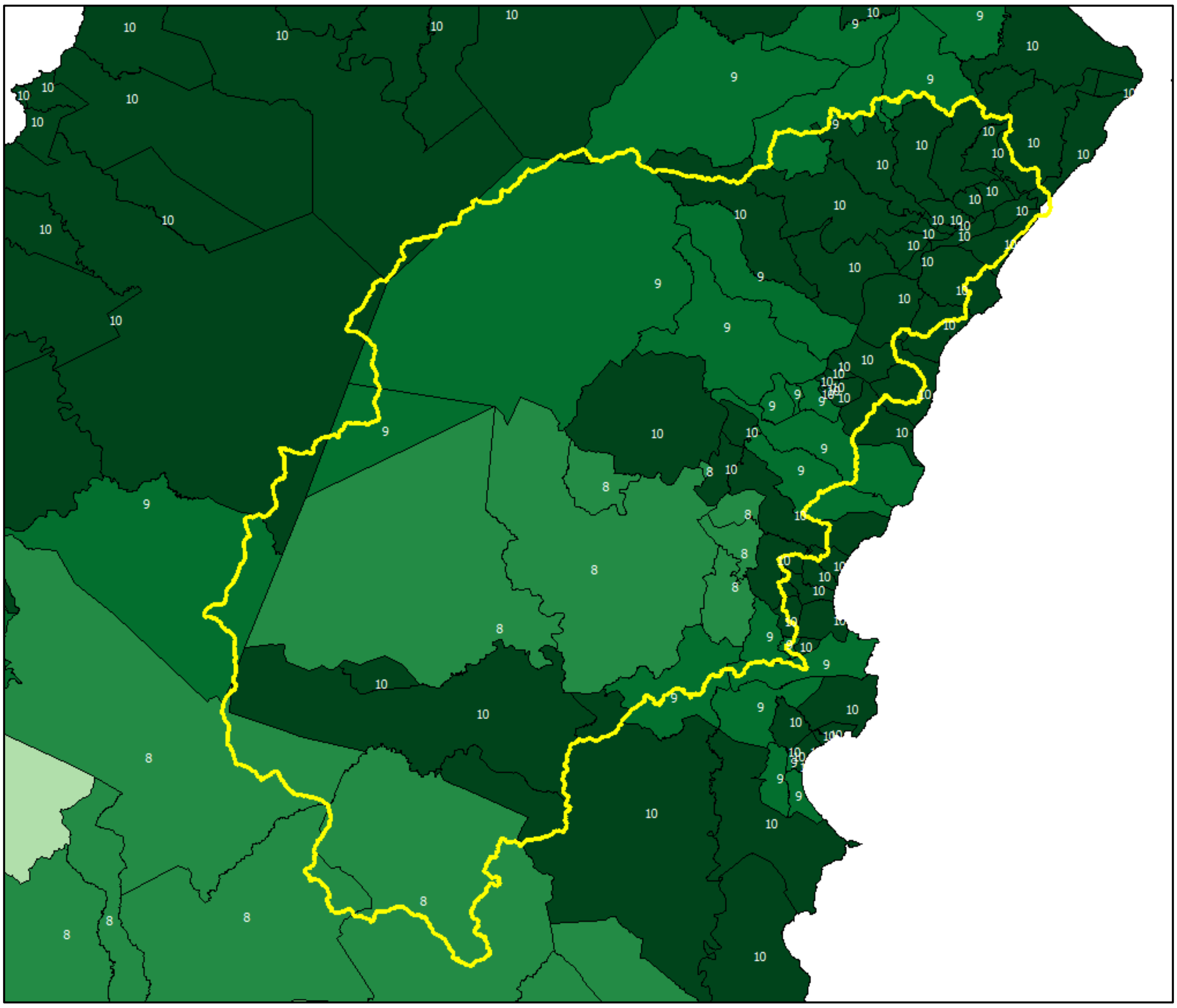

Figure 6.6: Socio-economic deprivation levels in the Waiapu catchment (Note: Darkest areas in the catchment are 10 on the New Zealand Deprivation Index, and the lightest are 8 (on scale of 1-10). A score of 10 means the area is within the most deprived 10% (lowest decile in the country).

The material circumstances of the people of the area can also be seen in the total family income statistics: in 2006, the median family income for East Cape was $30,600 and for Ruatoria $28,500, while for the nation as a whole the median family income was $59,000. The low incomes reflect the lack of employment, and comparatively high levels of family dependence on benefits (e.g. 24% of families in Ruatoria, and 17% in East Cape were receiving Domestic Purposes Benefit compared with 8% for the nation), invalids benefits, sickness benefits, and unemployment benefits.

6.3.5 The Waiapu catchment in 1986: Cyclone Bola and Forest Service disestablishment

6.3.5.1 Material wellbeing

Prior to Cyclone Bola, the people of the Waiapu catchment were already significantly disadvantaged economically and in terms of access to opportunities (indicated through, for example, the availability of employment, types of employment and educational attainment). There were 120 people recorded as unemployed and actively seeking work (or 10% of the labour force, compared with 6% for rural New Zealand and 7% for the nation). The poor socio-economic situation was such that the East Coast had been designated by government as a priority area for regional development. In 1986, Waiapu County, as today, had a much higher dependency ratio than for New Zealand as a whole, largely due to the high numbers of children and young people.

Figure 6.7 shows that the Waiapu catchment residents had comparatively low incomes for the region, with higher proportions of people falling into the low income categories. A meaningful comparison with national incomes is not possible at the time due to high proportion of missing information on incomes for those on the East Coast and possible resistance to government census enumerators at the time.

Data for Waiapu County in 1986 shows that the area had a greater proportion of low income earners than nationally with 95% earning under $25,000 per annum, compared with 70% for the rest of New Zealand.

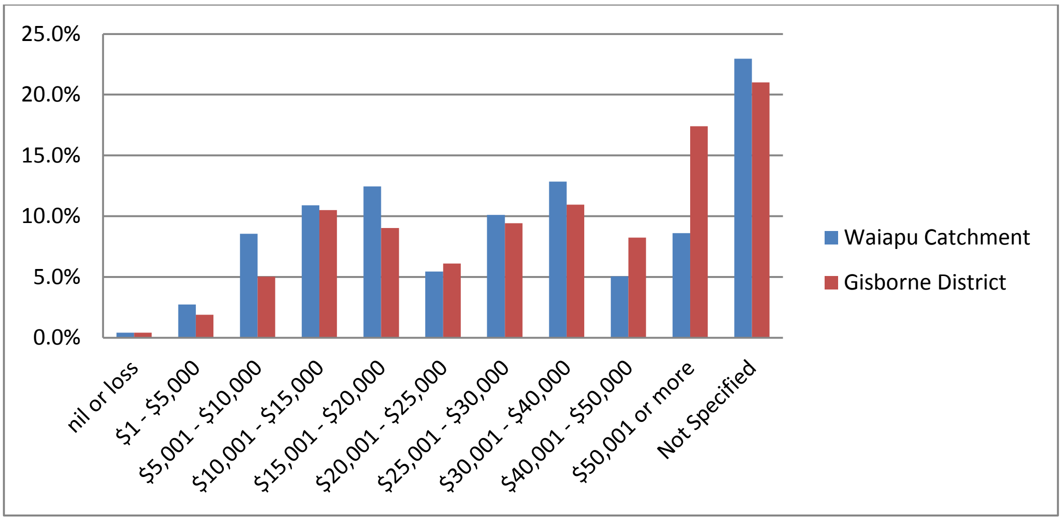

Figure 6.7: Personal income for the Waiapu in 1986.

6.3.5.2 Shock events to the community

It‘s clear that even prior to Cyclone Bola the Waiapu area was disadvantaged. The situation was made worse after 1985 (before Cyclone Bola) when the Government corporatised (and later privatised) the New Zealand Forest Service and laid off forestry and related workers in Ruatoria, Tokomaru Bay and elsewhere. Some also lost their Forest Service houses. The end of Government subsidies also reduced wage employment in agriculture, such that the number of unemployed farm workers registered across the district more than doubled. Loss of primary sector jobs and a rural downturn had a marked and ongoing effect on the rural Māori community and local social and economic conditions. Cyclone Bola and the associated destruction of property and infrastructure therefore made for a ‗perfect socio-economic storm‘ by the end of the 1980‘s.

6.4 Using a Ngāti Porou cultural framework to describe a desired state

The framework in Appendix 9 describes a ‗desired‘ state for the Waiapu catchment that integrates social, cultural and economic values and aspirations into a series of categories that reflect issues identified by Ngāti Porou through this research. Individual indicators with each category may be used to understand past states of the catchment and progress toward a desired state. These indicators are provisional and require further refinement and consultation with Ngāti Porou but serve as a valuable starting point for discussion. They may also be refined and modified over time to reflect changes in priorities and needs, or conditions. These indicators also provide a framework against which the impacts of any intervention within the catchment may be assessed. It is hoped that the framework fairly and honestly reflects a worldview of Ngāti Porou. The indicators are grouped under the following criteria:

1. The Waiapu and the Catchment
2. Environmental Indicators
3. Cultural Indicators
4. Mana Motuhake
5. Economic Indicators

Jollands and Harmsworth (2007) refer to the need for active engagement of all sectors of society in the development of indicators for the following reasons:

- It may help to reduce or remove ‗bounded rationality‘. For example, ‗when community is faced with a complex problem, individuals or groups might wish to pool their limited capabilities through discussion and so increase the odds of making a good choice (of indicators)‘.

- It adds weight to and increases the legitimacy of the indicators developed and their uptake.
- Improves the quality of decisions ‗in terms of distributive justice‘, for example, ‗participation may improve the allocation of unevenly distributed information leading to better decisions‘.

They also state that as Māori have such very strong and deeply held values and perspectives on inter-generational sustainability arising from whakapapa, kaitiakitanga, tikanga and ‗from tribal expectations‘ - that these in themselves ‗lead Māori to pursue monitoring that measures progress towards desired cultural goals such as enhancement of cultural resources and cultural well-being‘.

6.4.1 A summary of a ‚desired' state for the Waiapu River and catchment

Members of Ngāti Porou have identified that they desire:

- A clean river, with drinkable water that flows freely,
- A place to swim, play and enjoy the waters safely to contribute to the re-invigoration of the relationship between the people and the environment,
- Control over the river and its catchment as kaitiaki and able to decide and influence the protection and sustainable use of the Waiapu and reduce the sources of pollution to the awa and use matauranga that was honoured, respected and relevant to restore the catchment,
- A river was where kapata kai is bountiful with flora and fauna to sustain Ngāti Porou and in turn for Ngāti Porou to sustain the river,
- Restoration of the relationship that the people once had with the River together with greater responsibility for land use choices and how they effected the Waiapu; and,
- The restoration of native forest and protection of those areas of native forest that remain.

Ngāti Porou want to ensure that they do not pass the river onto future generations worse than what its current state, to at the very least, do no further harm to the River and its catchment.

It is evident from the research that Ngāti Porou regards the current state of the Waiapu River and its catchment of grave concern. There is a real sense of pain and fear over the condition of this cultural icon. They consider that erosion problems have plagued the area for generations and there is a feeling of resignation from many of the kaumatua interviewed for this project.

6.5 Critical evaluation of current efforts – East Coast Forestry Project (ECFP) and Land Overlay 3A (LO3A) – with regard to social, cultural and economic aspects of the erosion problem

6.5.1 Using selected headline indicators

The following headline criteria and indicators have been selected to measure progress toward a ‗desired' state for the catchment in the current policy environment and to evaluate the East Coast Forestry Project (ECFP) and Land Overlay 3A (LO3A). These indicators have been selected on the basis of their contribution to the wellbeing of Ngāti Porou, as a representative indicator of a key issue, or on the basis of their relationship to erosion, i.e. first order (direct) or second order (indirect) effects (please see Chapter 5). The remaining indicators are also of great importance to the wellbeing of Ngāti Porou but have not been reported on in this research as they were deemed to be third order or induced effects of erosion or too difficult to report on.

The table below includes observations on past conditions in the catchment and an interpretation of the current state based on the best information available during the course of this research project. The observations on the past conditions also serve as rationales which help to explain the relevance of, or need for the indicator by Ngāti Porou. It may be assumed that each indicator is linked to an event or state or value framework. Together they provide a tool against which progress may be assessed. For some indicators, information is unknown or unavailable; however, they have been retained as they help to present a conceptual understanding of the effect of erosion on Ngāti Porou. Information on the status of each indicator below represents a provisional assessment of the indicator within the current policy environment and against efforts to control erosion in the catchment.

Criterion 1: Ngāti Porou and the Waiapu and its catchment

Category	Indicator	Observations based on past conditions in the catchment	Observations on the current state	Status within the current policy environment and against efforts to control erosion in the catchment	Assessment of indicators against LO3A and the ECFP
Socio-Economic *"The river is sick so we are sick."*	Ngāti Porou are never hungry and can feed themselves and their whanau from the land. *"We want to get back to fishing and catching whitebait by the bucketful* (Maro pers. comm. 2011).	The land, the river, the forests, the mountain, the ocean, and the people are intricately woven together in the nature of what it is to be Ngāti Porou (T. Warmenhoven, pers comm. 2011). *"Ko te whenua te wai-u mo nga uri whakatipu." In English this means "mother earth, through her placenta, provided nourishment and sustenance for her offspring."* (Harmsworth et al., 2002, p19). *"She [the Waiapu] is a living entity, as everything is life, whether it be plant life, or human life, or mother earth. When you look back in our stories and histories, the earth has always been our mother and nourishes us. That's because we are part of one and the same in our creator."* (Harmsworth et al., 2002, p28). *"The whenua, including all waterways, is Papatuanuku, the nourishing provider, and the*	*"We are losing our mana. The river is eating away at the land. Without this land we are nothing."* (Harmsworth and Warmenhoven, 2002, p7).	Presumed not achieved.	LO3A: Is believed to be having a positive impact on the catchment and improving indirectly the health and well being of the river (awa) and its people. ECFP: Positively impacts the catchment and improves indirectly the health and well being of the river (awa) and its people.

		protector of all living things. Together with Ranginui, the air we breathe, she allows us to use and exploit elements of her that are necessary for our survival. Through life we remain her dependent offspring and in death we return to her." (Harmsworth et al., 2002, p28).			
Health *"Most of the knowledge (of Rongoa) and experts came or resided in the Maraehara catchment, this was attributed to the regenerated forest there. They had the knowledge base because of the forest."* (T. Warmenhoven pers. comm. 2011).	Areas of harvesting for rongoa are not negatively affected by erosion.	Unknown, however it is reasonable to assume that species used for medicinal purposes would have been more common and widely distributed prior to the forest clearances of 1880-1930's. The loss of native forest since 1880 associated with a loss of cultural knowledge suggests that both the rongoa resource and information relating to its use has been significantly lost.	An evaluation of current uses of rongoa species was undertaken by Harmsworth 2002 p84-85, examples include: kawakawa, red matapou, kowhai, makomako, harakeke, poroporo etc. Current impacts of erosion on rongoa species is unknown.	Presumed not achieved.	LO3A and ECFP: If planting native species or indigenous reversion is encouraged - this may improve the store of rongoa and contribute to the maintenance of matauranga Māori.
Education *"We need to sit down our young people and get them to listen. A few hours is not enough there are very few of us left that can talk. There is a lot of nursery work to be done. We need to be the conscience of the river and to be positive about the river. Only*	Ngāti Porou has access to environmental and other land-use advice and information which supports the aspiration of Ngāti Porou for their land.	A raft of reports, projects and proposals have been developed for the catchment (see the timeline above and policy scans).	Based on Harmsworth et al. (2002) (p61) there is a perception from Ngāti Porou that there is a mismatch between their aspirations and information available. *"The locals – tangata whenua – need to work out the future strategy for our land development. The people have an affinity to the land, that goes beyond economic viability."*	Awareness improving.	LO3A: Access to information regarding 3A areas is readily available and the maps associated with this work can assist in land management. ECFP: Information exists and where there is a need

then can we keep our streams clear. To have our river back to where it should be we need to work on ourselves." (Maro, pers. comm. 2011).			*" We can understand their science but they can't understand our ways."* (T. Warmenhoven, pers comm. 2011). Further information is required to support Ngāti Porou in land use decision-making, i.e. viable for forestry or other activity.		relationships may be built between the landowner and MAF.
Recreation *"There are still areas you can swim but you don't know what you are swimming in!"* (Kaa, pers. comm.)	Traditionally recorded swimming areas used by Ngāti Porou Whanau again.	Unknown.	Unknown.	Presumed not achieved	LO3A: May contribute to improved water quality. ECFP: May contribute to improved water quality.
	All schools are using the Waiapu for swimming and other recreational activities.	Harmsworth et al. (2002), (p66) states that in the summertime, some schools used the river for swimming: Waiorongomai school swam in the Tapuaeroa; Waiomatatini in the Waiapu; Tikitiki in the Poroporo.	Two schools (Makarika and Mata) continue to swim in the Mata. Today other schools use pools (Harmsworth et al., 2002, p66).	Presumed use declining.	N/A
	Surface water activities carried out by Ngāti Porou on the Waiapu regularly.	Unknown.	Unknown.	Unknown.	N/A
	River crossings are common to meet with neighbours.	Before the development of roads and bridges, Ngāti Porou relied upon waterways to access a range of services and resources (Harmsworth et al., 2002, p54).	Current level of use unknown.	Presumed declining.	N/A

	No adverse health effects from swimming in the waters of the Waiapu catchment.	Water quality in the streams and rivers of the catchment is thought to have declined over the last century. Though evidence suggests a level of acceptance of the condition of the rivers and their water quality by some local people. (Harmsworth et al., 2002, p55).	Unknown.	Unknown.	LO3A: May contribute to improved water quality. ECFP: May contribute to improved water quality.
Communication *"You used to be able to talk to your neighbours and now you can't hear them."* (Maro, pers. comm. 2011).	All Ngāti Porou are aware of the issues facing the Waiapu and its ahi ka and are engaged in its restoration.	Harmsworth et al. (2002) refer to community acceptance of the need to for further education on environmental and cultural issues generally in the catchment. (Harmsworth et al., 2002, p132)		Presumed some increase in awareness.	LO3A: Awareness of 3A contributes to the wider awareness of erosion and associated problems. ECFP: Awareness of ECFP contributes to the wider awareness of erosion and associated problems.
	Whanau in Tikitiki can speak across the river to the whanau at Te Horo without yelling.	Unknown.	Unknown.		N/A
Infrastructure *"Roads? What roads? Tracks more like it."* (Kaa, pers. comm. 2011).	Ngāti Porou communities are no longer isolated due to land slips and/or road closures.	There have been numerous events that have damaged both bridges and roads to make them impassable. Storm and Flood event records for the Waiapu catchment are given in	Based on anecdotal comments during this research, it is the view of some Ngāti Porou that the ‗clogging' of the river with sediment causes hang ups	Presumed no improvement.	LO3A: N/A ECFP: may lead to road construction and better

		Harmsworth et al. (2002).	with trees falling in the river with the potential to cause major damage to infrastructure like bridges and roads in the district.		maintenance due to harvesting requirements. High use can also deteriorate roading infrastructure.

Criterion 2: Ngāti Porou - environmental indicators

Ngāti Porou have a continued relationship with native flora and fauna within the Ngāti Porou takiwa. Ngāti Porou traditionally had a symbiotic relationship with both plants and animals understanding their cycles, habitats and seasons. Loss of matauranga, changing habitat, over harvesting, pests and land use impacts are thought to have seriously affected the health and well-being of taonga species.

Category	Indicator	Observations based on past conditions in the catchment	Observations on the current state	Status within the current policy environment and against efforts to control erosion in the catchment	Assessment of indicators against LO3A and the ECFP
Kapata Kai *"There is no kai left in the river, bugger all. People still go. People go out with the seasons. There is a time for fish. The fish still migrate but not as plentiful because there is no habitat. Our young guys are still eeling. They are going further up. Most of the pakeke have had areas destroyed, tuna, whitebait. You can't get down to the river, and the rocks that indicated certain species are gone."* (Maro, pers. comm. 2011).	Tuna and other kai is bountiful in the river and can easily regularly sustain Whanau and supply tribal events.	A century ago all freshwater and coastal fish including kokupu, inanga, lamprey and both species of eels were abundant in the catchment. Harmsworth et al. (2002) refer to the importance of tuna to whanau and hapu as a staple food source. They also point to a decline in distribution based on local evidence and experience. (Harmsworth et al., 2002, p56-57).	The NIWA Fish Database contains information on species distribution within the catchment. Further research is needed to identify ‗sustainable use‘ levels for Ngāti Porou. Richardson and Jowett (2002) looked at the effects of sediment on fish communities on the East Cape. They found that suspended sediment yield, of which the Waiapu was the highest, had a significant negative effect on fish density.	It is perceived by Ngāti Porou that erosion has greatly affected species traditionally eaten and used within the rohe. Both the diversity and abundance of species like pekapeka, kereru, kahawai, kokopu, tuna and weka have been identified or are thought to be in decline or at levels that make their use as a resource unsustainable. Kahawai in particular are assumed to have been affected by increased sedimentation however some kahawai and kawae are reported to have returned to the ngutu awa after Cyclone Bola. The ability to catch fish due to high sediment loads may also make fishing within the	LO3A: May contribute to improved water quality and thereby riverine habitats and fish stocks. ECFP: May contribute to improved water quality and thereby riverine habitats and fish stocks.
	Inanga can be harvested sustainably by the ‗bucket full‘ (Maro, pers. comm. 2011).				
	Kokopu are part of the				

	staple diet of Ngāti Porou again.			main stem of the river extremely difficult. It is also noted that the use of some species will have declined as societal preferences have changed over time. Nga ika wai Māori (freshwater fish) – Harmsworth et al. (2002) (p56) describe local observations that the distribution and abundance of freshwater species has declined with the clearance of native bush and impacts of erosion.	
	Watercress is plentiful and safe to eat.	Unknown, but presumed more abundant.	Harmsworth et al. (2002) (p56) mentions that pollution and loss of drains has made safe watercress sites difficult to find.	Presumed decline in the availability of the resource.	LO3A: If planting is undertaken with native species this may improve the store of useable resources and contribute to the maintenance of matauranga Māori. ECFP: If planting with native species or supporting reversion this may improve the store of available resources and contribute to the maintenance of matauranga Māori.
	A broad range of non-cultivated foods are easily identifiable and part of the regular diet of Ngāti Porou in the catchment.	A wide range of non-cultivated foods have been recorded as being used by Ngāti Porou in the catchment. Their use will have declined over time through loss of knowledge, bush and habitat loss (Harmsworth et al., 2002, p58, p78-79) and societal preferences.	Unknown.		

	The four species of Pekapeka are commonly found in native forests in the Waiapu catchment.	Four species of Pekapeka or bat are recorded in Harmsworth et al. (2002) as being eaten by old people. They were recorded in a range of habitat types (Harmsworth et al., 2002, p76)	Unknown.	Presumed declining or extinct in the catchment.	LO3A and ECFP: If planting with native species (including indigenous reversion) – may improve biodiversity and habitats for desired species. Managed plantations (both exotic and indigenous) for exotic pests and diseases may also support native species.
	Kereru and Kaka are found at similar numbers as in 1936 in the Poroporo catchment and the Waiomatatini/Northern Waiapu area.	Kereru and Kaka were thought to be abundant 75 years ago in this area. Their decline is attributed to habitat loss (Harmsworth et al., 2002, p58).	Unknown.		
	Weka are found in the Waiapu catchment.	Weka are thought to have disappeared from the catchment following Cyclone Bola Harmsworth et al., 2002, p59).	Unknown.		
	Kapata kai areas are no longer negatively affected by erosion.	Knowledge of kapata kai, its use and location, would have been held within the community and been vital to the wellbeing of local people (Harmsworth et al., 2002, p55).	Unknown.	No comment	LO3A and ECFP: If planting with native species (including reversion to native forest) – may improve biodiversity and help to restore kapata kai. Managed plantations may also support native species thereby supplementing kapata kai.

Water *"We haven't got clean water, it is totally unsafe and sadly the Kahawai have seemed to have packed up and left."* (Kaa, pers. comm. 2011).	Underground springs are used and protected.	Harmsworth et al. (2002) (p55) describes the importance placed on springs during times of drought by local people.	Unknown	Springs are important water bodies for Ngāti Porou providing drinking water and for use for cultural purposes. Storm events and associated erosion are thought to affect access to springs or contaminate them.	LO3A and ECFP: Further afforestation or reversion to native forest in the catchment will improve water quality.
	Water quality from the Waiapu is to a standard where it is clean enough to drink.	Harmsworth et al. (2002) refer to the concerns expressed by some local people of ‗impacts' of dumps situated alongside the Waiapu River. Quantitative data is required.	High sediment loads has meant that little water is taken from the River for drinking purposes[1].	Presumed declining or no improvement.	LO3A and ECFP: Further afforestation or reversion to native forest in the catchment will improve water quality.
	Water quantity is sufficient for both economic and cultural activities.	Unknown.	Unknown.	Harmsworth et al. (2002) comments that many local people see an important role for native forests in sustaining water flow in the catchment and thereby	

[1] http://landandwater.co.nz/councils-involved/gisborne-district-council/waiapu-river/state-of-the-waiapu/

				quantity in the catchment.	
Climate *"We cannot control the climate we cannot change the weather".* (Paenga, pers. comm. 2011).	Ngāti Porou are engaged in climate change adaptation activities to increase their resiliency to extreme weather events.	A perception that the climate was changing amongst Ngāti Porou began to emerge after Cyclone Bola (Harmsworth et al., 2002, p51).	Unknown.	Presumed increase in awareness.	LO3A and ECFP: Further afforestation or reversion to native forest in the catchment will result in increased carbon storage.
Ngahere *"Native has got to go right through here. Pine is ok in its own place, not everywhere. We are not getting any of the money from forestry. We want manuka, kanuka, flax."* (Maro, pers. comm. 2011).	Large expanses of Ngāti Porou lands are in reserves for native forestry.	In 1840, approximately 80% of catchment was still under native forest. Harmsworth et al., 2002, p11). In 2002, Harmsworth et al. (2002) (p141), reports that 21% remains under native forest cover but with little active management.	Unknown.	Some Ngāti Porou, regard the restoration of native forest as a key component of any strategy to restore the health of the catchment. Harmsworth et al. (2002) also refer to the restoration of native fauna and flora as a contemporary issue (p132).	LO3A and ECFP: Planting with native species or reversion to native forest will help to achieve a many of the aspirations of Ngāti Porou.
	Nga Whenua Rahui and carbon agreements are widely established in the Waiapu catchment.		Nga Whenua Rahui uses incentives to encourage voluntary conservation of indigenous biodiversity on Māori land. Harmsworth et al. (2002) (p141) reports 3733ha under Nga Whenua Rahui.	Awareness increasing	
	Afforestation is the core business of Ngāti Porou.	Ngāti Porou Whanui Forests Ltd (NPWFL) was established in 1989 offering partnerships to	(NPWFL) is looking at carbon and the New Zealand ETS to further recruit Ngāti Porou	Unknown.	LO3A: Contributes to the afforestation of the region.

		develop forests in the region.	lands for forestry opportunities. They currently have approximately 8,000 ha in exotic forest and also manage forests on behalf of other clients.		ECFP: Important enabling mechanism to support Ngāti Porou afforestation aspirations.
	We are sustainably managing harvesting to avoid mass deforestation and have a managed system.	Unknown.	Unknown.	Concerns were expressed during this research over ~~a~~ggressive harvesting techniques" and the aggravating affect they may be having on erosion in the catchment.	
Land *"…30 acres lost on my farm. The flats are gone. Bridges are being replaced. A lot of the land was lost after Bola. Every bridge up the river was affected with Bola and the 1938 flood, with the large volumes of water."* (Paenga, pers. comm. 2011).	The areas of Ngāti Porou land lost or seriously degraded over time by land use have substantially reduced from 1988 numbers.	Please see companion reports for the state at Cyclone Bola.	Many blocks that are eroding or susceptible to erosion are still being farmed by Ngāti Porou (Harmsworth et al., 2002). Large tracts of land have been lost by Ngāti Porou landowners to the Waiapu. Eru Paenga of Te Horo stated that 300 acres of his farm had been eaten by the river (Paenga, pers. comm. 2002).		LO3A and ECFP both contribute to erosion control.

Criterion 3: Ngāti Porou - cultural indicators

Category	Indicator	Observations based on past conditions in the catchment	Observations on the current state	Status within the current policy environment and against efforts to control erosion in the catchment	Assessment of indicators against LO3A and the ECFP
Matauranga Māori *"It's got umpteen names. There's Waipau koka huhua. There is a magnificent new poi that Hinetu Ngarimu wrote for her women's group, and it is all about the river and its history and the whakatauki, so you know this is significant to people's cultural kōrero."* (Kaa, pers. comm. 2011).	Karakia are revived through the identification and protection of natural springs.	Springs have played an important role in maintaining the wellbeing of local people who draw clear links between the health of springs and the presence of native forest cover (Harmsworth et al., 2002, p55).	Unknown.	Unknown.	
Waahi Tapu *"That maunga Pohautea, there is a moteatea, Ngatorou and its based on Pohautea, Hikurangi is tapu but so is Pohautea.* *We call it the guardian of the river and at the rate of erosion as it has been in the last few years Pohautea will be gone."* (Atkins, pers. comm. 2011).	Waahi tapu are not at risk from being negatively impacted by erosion.	Unknown. Given the level and intensity of settlement in the catchment over many years, there are likely to be numerous sites of cultural, spiritual and archaeological importance in the area.	Unknown. Beckwith (2007) describes how many sites during her survey had been destroyed or damaged by a number of processes, including erosion.	Presumed declining with continued loss according to Beckwith (2007).	LO3A and the ECFP may contribute to the safeguarding of waahi tapu sites where measures are put in place as part of sustainable management plans.

Criterion 4: Ngāti Porou - mana motuhake

Category	Indicator	Observations based on past conditions in the catchment	Observations on the current state	Status within the current policy environment and against efforts to control erosion in the catchment	Assessment of indicators against LO3A and the ECFP
"There are things that can strengthen our argument like contiguous ownership." (T. Warmenhoven, pers. comm. 2011).	Ngāti Porou hapu are making decisions over erosion management policies and programmes for the Waiapu.	Various initiatives have focussed on one to one engagement with landowners by various agencies with an interest in the catchment.	Ngāti Porou have prepared hapu environmental management plans based on hapu values and whakapapa and to identify aspirations and plan practical solutions to problems (Harmsworth et al., 2002). More knowledge required of individual Māori land ownership.	Presumed improving. There appears to be a growing recognition amongst some Ngāti Porou of a need to develop strategic, integrated and holistic solutions to the degradation of the catchment and decline in the wellbeing of its people: *"The issue is mana motuhake is not erosion. We need a holistic view to change, not just talking about the symptoms like erosion. Cause when you say erosion all we can talk about is erosion. These people (kaumatua present at the hui) can talk about the Waiapu, a few of our generation can talk about the Waiapu, but I doubt many of the next generation can do it. We need to talk about the big picture."* (P. Pohatu, pers. comm. 2011).	LO3A: Is a compulsory programme and it is the belief of Ngāti Porou that they are not part of the decision-making process. ECFP: It is the view of Ngāti Porou that they are not integral to policy design and implementation.
	Ngāti Porou have effectively created and implemented successful erosion policies that are driven by the people on land that they	Erosion has always occurred in the catchment. However, forest clearances have led to a level of erosion that is significant on a global scale. This shock to the community and landscape has been increasing for	Through this research some Ngāti Porou have indicated a desire to explore traditional approaches to ways of managing erosion. To reinvigorate the relationship of Ngāti	No Comment. *"There is a whole lot of land disappeared out there. We haven't yet reached the final destruction of the Waiapu. It started way back. It doesn't matter what we do on this side of the bridge. We can't stop anything that is already created, it's*	LO3A: Is a compulsory programme and it is the belief of Ngāti Porou that they are not part of the decision-making process. ECFP: It is the view of Ngāti Porou that they are not integral to policy

	directly control.	over a century. The ability of the community to respond has been hindered by a number of factors including: a lack of resources, human capability and capacity, a lack of capital and a perceived inability to shape policy and operational management programmes (Harmsworth et al., 2002).	Porou with the river and to pass-down traditional knowledge to new generations.	*going to take another 100 years."* (Maro, pers. comm. 2011).	design and implementation.
	Ngāti Porou are engaged with central government to ensure that national policies do not increase the degradation of the Waiapu.	It is the belief of many Ngāti Porou that they have been left outside of strategic decision-making processes and that the impacts of past policies have had major impacts upon them, for example, the disestablishment of the Forest Service and subsequent sale of the forest estate.	*"We are the caretakers of the land for the duration of my life. We know what is happening but we have not got the teeth to change things. What is the sense of talking about the treaty when we are not equal?"* (Maro, pers. comm. 2011).	Presumed improving. *"Today, tangata whenua are becoming increasingly aware of past errors regarding misuse and mismanagement of land. Many agree that repetition must be avoided in future planning. Our people died protecting our land. This place would have been beautiful. Today we are trying to save what we ruined. We have to be very conscious and aware of how we live in our environment…. Some people see [sic] the land to make dollars, money. That is not necessarily applicable to all ecosystems. Some areas are for that purpose. Not all areas are for exploitation." (*Harmsworth and Warmenhoven, 2002, p7).	LO3A: N/A ECFP: It is the view of Ngāti Porou that they are not integral to policy design and implementation.

Criterion 5: Ngāti Porou - economic indicators

Category	Indicator	Observations based on past conditions in the catchment	Observations on the current state	Status within the current policy environment and against efforts to control erosion in the catchment	Assessment of indicators against LO3A and the ECFP
Technology *"LIDAR mapping could be an answer for us. They are taking tonnes out of the river, but they might be taking it out at the wrong place. We could use it to improve the river."* (Maro, pers. comm. 2011).	Ngāti Porou have developed IT opportunities and products in communications, erosion control and land management tools.	Unknown.	Harmsworth et al. (2002) explained how Ngāti Porou desire to have better access to mainstream science and technology.	Presumed improving.	LO3A and ECFP: Awareness of the policy contributes to the awareness of erosion.
	Ngāti Porou have identified and are establishing alternative routes and transport options along the East Coast to improve roading options that will not be effected by erosion prone areas.	Unknown.	Unknown.	No comment.	ECFP: May enable road construction and maintenance to support harvesting activities. High levels of usage may also result in a deterioration of roading infrastructure.
Investment *"Give the problems of the Waiapu back to the government. They are the ones who buggered it up. They are the ones who encouraged farming and the cutting down of the native trees, those Pakeha farmers. (All those Pakeha farmers have sold up and shipped out.) Let them fix them it up. Our mokopuna should get it back when it is fixed. The mana of* Ngāti *Porou will always be the*	Ngāti Porou are actively investing in erosion prevention and remedial action collectively on an annual basis to an agreed strategy.	Unknown.	Unknown.	Unknown.	LO3A: Compulsory so Ngāti Porou have to invest in this programme and its delivery. ECFP: Positive uptake by Ngāti Porou initially however this may be declining. Retrospective payment a barrier to uptake by Māori.

awa tapu, they cannot take that away from us." (Maro, pers. comm. 2011).					

6.5.2 Ngāti Porou perspectives on past and current policies to control erosion

The interviews and hui held over the course of this research identified a number of perspectives on the erosion problem in the Waiapu catchment. Significantly, most of the participants felt that the issue of erosion is just one area of focus, a symptom of a wider disconnection from the river and a degradation of the relationship between the river and Ngāti Porou. That the issue is fundamentally, the need for a holistic vision that embraces the aspirations of the people and the need to restore and enhance a damaged landscape. That the people, who belong there, are actively engaged in the process of healing.

> *"The issue is mana motuhake is not erosion. We need a holistic view to change, not just talking about the symptoms like erosion. Cause when you say erosion all we can talk about is erosion. These people (kaumatua present at the hui) can talk about the Waiapu, a few of our generation can talk about the Waiapu, but I doubt many of the next generation can do it. We need to talk about the big picture."* (P. Pohatu, pers. comm. 2011).

Discussions also focussed on traditional Ngāti Porou ways of managing erosion. To reinvigorate the relationship of Ngāti Porou with the river and to pass-down traditional knowledge to new generations. Several kaumatua expressed concerns over the loss of matauranga and the ‗rush of youth to do things' without knowing the understandings or messages held in traditional knowledge.

There are mixed views on the schemes used to control erosion, particularly with respect to the use of exotic species in production forests and the concerns regarding aggressive harvesting and its contribution to accelerated erosion. Many Ngāti Porou are supportive of afforestation but are looking to alternative native species to reinvigorate more than just the local economy. From interviews, landowners see the current opportunities with carbon as a way to encourage afforestation and enter into agreements to reserve areas that are erosion prone. There is a growing understanding that there are few other options to reduce erosion in the catchment other than afforestation and with this is openness towards Nga Whenua Rahui as a mechanism to achieve these aspirations.

Environmental impacts of erosion on the Waiapu have been widely felt amongst Ngāti Porou. The current land use and management regimes are clearly identified as the main contributors to the serious erosion experienced in the catchment.

"The young people they light a fire on the river. We were never allowed to light a fire along the river. The fire along the river should not be close to where they are fishing. The only fire we used to see is when they are fishing for kahawai and they are cold and then when they warm up they can go back in again. But anywhere else up river we don't light fires or the river will come and take that part of the land away and maybe it is still taking it." (Maro, pers. comm. 2011).

Education is seen as key to a re-evaluating current approaches and land uses which largely are perceived to be failing and to inform any attempt to restore indigenous forestry to the catchment. It was believed that thought would revive the land and habitat again. Genuine grief was apparent in the workshops over the loss of kai, but still a sense of hope that the young were still hunting and gathering in the old areas where they could. A desire to safeguard through reserves important areas of land, and avoiding pine where possible, was also expressed.

Recognition of the need to develop an infrastructure to support indigenous forestry, for example, the revival of local nurseries for native tree propagation was commented on. Wider discussions about the importance of kanuka and manuka were explored, in particular with respect to the use of manuka as a nursery species.

"The manuka and kanuka will be the nursery for us and our saviour. If you leave it long enough the other species will grow… put that native forest back to where it belongs. We might need some fast growing trees to start us off then re-establish the native. We want nurseries to start our natives but we need the money to plant. That is the only way that I can see to fix our problems." (Maro, pers. comm. 2011).

Forestry is perceived to be making money for non- Ngāti Porou investors and forest companies. A rush to the East Coast with the introduction of the ETS has seen, it is believed, Ngāti Porou are being cut out of schemes and thought to be increasingly marginalised by the larger forestry companies with greater access to capital.

"Five years ago we could get the money (from ECFP), but now it's open to everyone and they want their carbon forests on our lands, the big companies are cutting us out." (Mackey, pers. comm. 2011).

The use of a single species in forestry remains a concern for many local people. While *Pinus radiata* is accepted, it is not viewed as the only species that could be planted in the catchment.

Afforestation schemes were supported but not widely understood by the participants. Closely allied to this, is a view that while subsidies are helpful, as they are managed externally to Ngāti Porou, there is a lack of influence on the decision making processes that is causing a level of mistrust of the system. They are seen as a short term solution until full control of the Waiapu is returned to Ngāti Porou. Furthermore, as subsidies available through the ECFP are paid out retrospectively, this is also seen as a major barrier to uptake. Participants wanted to see a scheme that better reflects the needs of Ngāti Porou.

Reservations of Māori land for environmental purposes were widely supported. However, longer term covenants including carbon agreements were considered risky due to the length of time involved. There was a view that further afforestation may lead to an increase in rates, which were already regarded as onerous given the level of service provision from the Gisborne District Council.

The influence of the Gisborne District Council was seen as a significant barrier to the exercise of Mana Motuhake and better erosion control methods on the Waiapu. LO3A was discussed, and the workshop participants demonstrated some confusion over the management process. However, it was clearly supported and its extension in certain areas identified as an effective tool. Fencing was also identified as a way to reduce the impacts of erosion.

> *"The main contributor to erosion is the gully erosion. You must fix up the gully erosion. This not going to cure it but it is a major factor. We have a land use change that compels those people with gullies on their lands to plant."* (Mackey, pers. comm. 2011).

> *"We want fencing. We need to focus on Pakeha land which is two thirds of the problem. Work has to be done up river in the catchment."* (Collier, pers. comm. 2011).

The introduction of ‗dolos' in the river was welcomed. However, there were concerns that these had been placed in areas that were not at a high risk of erosion. It was felt that more ‗dolos' were required but the costs for these were perceived as prohibitive. It was laughingly stated that they may have to use the car wrecks in the river instead!

> *"Dolos have come into effect in the last few years. Our Dolos were put in about two years later than they should … prior to these they were getting boulders and digging holes to deal with erosion. They were going to the Hukanui at the top of Tapuaeroa*

which has the biggest boulders that come from the mountains. They were taking huge boulders. They were causing us problems. They took all of these boulders for free and took them away. We could have been using these." (T. Warmenhoven, pers. comm. 2011).

Many anecdotal stories were told about the building of roads, bridges, and erosion control schemes against the advice of residents of the Waiapu.

"The spiritual force, you can't buy that. We should maintain this, it is more than a river! What about the stories of the Taniwha that we know about? What about when Tamenamena objected to the building of the bridge…Rikard was on the council that was deciding on the bridge. And he said those people at Rangitukia are telling you that you have the bridge at the wrong place. They (the council) said it was the ideal place with the channels and what have you. He (Rikard) said „well my wife is from there and her people are saying there is a Taniwha and Taniwha stories or not they are saying you should not build there'. Finally they put it in the right place away from the place where Tamenamena goes to have his daily swim. He is probably referring to underground streams and water courses that we cannot see that the old people were aware of. They explained them through taniwha. There are names of two women Taniwha. All that information is relevant. The spiritual views of the people must be taken into account." (Kaa, pers. comm. 2011).

"There are our people who know this place. The history of this place tells them where they should do erosion protection. They have made mistakes before because they just did not listen. The bridge was the first one down there. Go down there and take a photograph of the memorial stone that is still down there. There is one there out of three, where our people told them you can't build a bridge here, you cannot. But I suppose the language, you cannot. When you tell them you can't, they want to do it ... it didn't last, I don't think that bridge lasted more than 12 months." (Maro, pers. comm. 2011).

"When the Waiapu landfill was placed they did not understand that the location of this dump would negatively affect a sacred spring. It was contaminated and we used to carry our rites there." (T. Warmenhoven, pers. comm. 2011).

Concerns about gravel extraction from the Waiapu and licenses for that purpose were identified as further evidence of the loss of mana Motuhake felt by Ngāti Porou over the Waiapu River. A sense of frustration and powerlessness was clearly articulated with a passionate desire for Ngāti Porou to have control over the Waiapu and its future. Uneasiness was expressed at the lack of understanding of those who currently manage the Waiapu and the absence of a holistic view of the health of the river and its people.

> *"We can understand their science but they can't understand our ways."* (T. Warmenhoven, pers. comm. 2011).

Younger participants in the hui saw the future in co-management, resting the ownership of the bed of the river (as in the case of Ngāti Tuwharetoa and Te Arawa) with Ngāti Porou and in greater control over decision-making processes. It is clear that Ngāti Porou participants that took part in this research programme believe that increased Ngāti Porou influence and ownership over the future of the catchment is the only way that the future wellbeing of the River and the people may be secured.

> *"We are the caretakers of the land for the duration of my life. We know what is happening but we have not got the teeth to change things. What is the sense of talking about the treaty when we are not equal?"* (Maro, pers. comm. 2011).

> *"If we had authority we could compel people to change."* (Collier, pers. comm. 2011).

6.5.3 Review of the East Coast Forestry Project (2011)

The ECFP was reviewed as part of the Afforestation Schemes Review (MAF, 2011b). The review made an extremely brief assessment of the financial, environmental, and social costs and benefits of the ECFP and LO3A delivered to participating landowners and the community. The findings of the review in this regard are summarised below (Table 6.3). The high level comments associated with this assessment may further highlight the disconnection between community aspirations and policy development and monitoring.

Table 6.3: A summary of the financial, environmental, and social costs and benefits from the ECFP and LO3A to landowners and communities from MAF (2011b).

Stakeholders	Financial	Environmental	Social
Landowners	Receive grants for land treatment options. Some forests may not be viable to harvest. May receive carbon credits via PFSI or ETS. Cannot afforest scrub covered land.	Facilitates sustainable land use.	Supports more (sustainable) land use outcomes.
Communities	Incurs some direct costs through the ratepayer for administration of LO3A rules.		On-site sustainable land use benefits and downstream mitigation of flooding and soil deposition.

The ECFP may not have been taken up widely by Ngāti Porou for many reasons including:

- As the programme is focused on erosion control it fails to reflect or embrace wider aspirations of the community for a desired state for the catchment.
- The absence of a co-management or co-governance model (see Section 6.8) may have meant that the community has failed to see itself as an equal partner in the resolution of the problem through the ECFP.
- As a relatively disadvantaged community, many Ngāti Porou do not have access to finance or capital to support their uptake of funding packages.

6.6 Assessment of the size and scope of the social, cultural and economic aspects of erosion in the Waiapu catchment

6.6.1 Natural capital and the impacts of erosion on the Waiapu community

Human communities' depend on natural capital (e.g. water, air, soils, plants, animals, landscapes, and ecosystems) to meet their physical, cultural, emotional, intellectual and spiritual needs. From an anthropocentric perspective, the biophysical world provides various functions that sustain human individual and collective life. It follows, then that changes in the biophysical environment are likely result in changes in the human environment.

As noted earlier, when changes in aspects of human life for a particular people are significant they can be thought of as ‗social impacts" (Vanclay, 2002). Using this notion of an impact, it follows that biophysical changes arising from erosion in the Waiapu landscape and catchment will be seen as impacting on local Māori and communities where those changes:

- Significantly enhance or reduce the productivity of important/valued ecosystems,
- Significantly add to or diminish the quality or supply of important goods and services that are obtained from the environment and each other, or
- Significantly enhance or diminish people‘s cultural practises and expression, way of life, and sense of wellbeing.

The following tabulated analysis scopes out the actual and potential impacts on people and communities of the Waiapu catchment arising from erosion. It does not address directly, the effects of Ngāti Porou‘s loss of ownership and/or control over the land itself, the subsequent deforestation for pastoral agriculture, the afforestation of eroded and at-risk lands, and the introduction of industrial-scale public and private sector plantation forestry.

The analysis is based around key effects of erosion on biophysical functions, as derived from the Food and Agriculture Organisation and elaborated by Dominati et al. (2010), and the categorization of human social impacts as proposed by Vanclay (2002) and describes flow-on effects and impacts on the local community. Analysis of the human social impacts for the Waiapu has also drawn on primary and secondary data from interviews and consultations with Ngāti Porou residents of the Waiapu area and the Gisborne region, as presented elsewhere in this report. Based on the analysis below, the major social, economic, and cultural impacts (size and scope) of the erosion problem may be summarised as follows:

- Flood, sediment and erosion damage to stocks and flows of critical natural capital that compromises the ability of local people to meet their needs, especially abundant good quality seasonal food, fresh clean water and other resources.
- Degradation and loss of natural capital within the catchment is likely to have contributed to on-going rural depopulation and a loss of human and social capital, with associated reduced community functioning, strength, reduced wellbeing, reduced cultural identity and expression, loss of services and economic marginalisation.
- High levels of social and economic deprivation which are not helped by a degraded landscape and eroded natural capital.
- A dependency and reliance on external intervention to address the problem at the catchment/landscape level.

- An awareness of a reduced connection between the people and the whenua (river, forest, and natural world) and each other, resulting in reduced physical and spiritual wellbeing.
- A loss of general and specialist knowledge of the environment and cultural practises associated with catchment-based livelihoods over time as a result of landscape change and the loss of a traditional resource base.
- A loss of economic development opportunities and options as a result of a degraded landscape.
- Direct damage to houses, infrastructure and productive land from increasing frequent and voluminous floods.
- A lack of engagement in catchment management decision making and planning is perceived to be preventing the community from pursuing its own vision of a desired state for the Waiapu catchment and hindering community engagement in the resolution of the problem.

6.6.1.1 Analysis: A Scoping of the impacts of erosion in the Waiapu catchment on local people and communities

IMPACT: LOSS OF LANDS IN UPPER CATCHMENT & SUB-CATCHMENTS					
Biophysical changes	***Impact/issue***	***Effect/outcome***	***Social/economic/cultural changes***	***Human impacts***	***Flow-on impacts***
Loss of soil nutrients, organic matter and soil moisture/water storage function. [Depletion impact]	Reduced plant and forest productivity.	Lower carrying capacity and productivity (pasture/stock/ trees).	Reduced income to landholder or farmer.	Lower household incomes. Loss of financial capital. Increased off-farm employment & commuting.	Lower economic standard of living. Increased debt burden. Lack of resources for reinvestment. Change in roles/ division of labour. Disruption to household & community functioning. Increased transportation costs.
			Reduced local employment.	Lower standard of living/wellbeing. Unemployment. Increased deprivation. Out-migration (urban drift) for employment e.g. of working-aged males). Population structure imbalances. Cycle of rural social and an economic downturn.	Increased demand on social services, institutions and families. Increased reliance on free-access natural capital (e.g. fisheries) & associated vulnerabilities. Loss of key human capital (e.g. social and cultural skills & knowledge). Reduced local services viability. Family & community disruption. Cultural dislocation. Shortages of human & social capital. Increased multi-dimensional disadvantage. Declining local community social and economic viability.
			Land use change.	Change in economic base of district (e.g. exotic	Potential increased diversification & resilience.

				afforestation). Less/more employment opportunity. Financial and human capital cost of changes.	Less year-round local employment.
			Land ownership change.	Reduced local control. Injection of new capital.	Weakening/strengthening of local institutions. Reduced community coherence. Increased economic opportunity if local investment/expenditure.
			Changes in land/farm management (imposed).	Financial costs/risks. Loss of sense of community control/authority/mana.	
Loss of physical support functions for natural forest flora & fauna (landslide etc.). [Depletion and ecosystem performance]	Ecosystem destruction.	Loss of habitat. Reduced forest area & forest production. Changes in supply of key flora and fauna.	Reduced availability/accessibility of wild foods. Reduced availability of forest materials/fibres etc. & chemicals. Loss of natural pharmaceuticals /medicines. Loss of biodiversity. Loss of recreational opportunity (e.g. hunting, walking, relaxing).	Nutrition/ health effects. Increased living costs. Loss of cultural practises and associated knowledge. Reduced independence /self-reliance. Changes in livelihoods strategies.	Reduced individual and collective health & wellbeing. Financial cost of substitutes. Reduced quality of living environment/amenity, and sense of place. Reduction in cultural integrity & identity. Psychological and spiritual stress/loss. Loss of local and regional cultural diversity.
Large-scale rapid landscape/ landform change e.g. (gullying, major	Change in signification /information function of environment. Reduction in	Changes in visual and aesthetic qualities of landscape Damage to physical capital	Reduced amenity and liveability of the environment. Direct physical risks to land-users.	Reduced personal and community wellbeing. Physical threat to land-users. Reduced sense of place.	Costs of reduced wellbeing. Injury or loss of life to people and animals. Financial burden on the local council, communities and landholders.

slips etc) [Depletion]	biophysical carrying capacity.	(farms etc.). Loss/damage to sacred and historic sites (Waahi tapu).	Decreased manageability and usefulness of land Reduction in capital value of land/farm etc Costs of repairing land and property (time, money)	Effect on personal and collective cultural identity and integrity. Reduced tourism appeal. Costs of replacing repairing infrastructure/physical capital.	Reduced access to credit & insurance. Reduced tourist stays - lower input to local economy.

IMPACT: SEDIMENTATION AND AGGRADING OF RIVER COURSES					
Biophysical changes	***Impact/issue***	***Effect/outcome***	***Social/economic/cultural changes***	***Human impacts***	***Flow-on impacts***
Changes in river morphology (bed width, bed height, etc.) and course. [Ecosystem performance]	Large scale river landscape and habitat change. Changes in estuary and coastal morphology.	Spread and braiding of riverbed/channel. Unstable river course. Reduced accessibility.	Reduced recreational opportunity. Reduced navigability of river/s. Increased environmental risks. Disruption to way of life. Change in environmental amenity.	Loss of swimming/recreational areas. Increased alternative recreational opportunity. Loss of fishing holes etc. Loss of river access and crossings. Reduced sense of connection to river.	Reduced sense of wellbeing. Reduced quality of life. Cost of accessing substitute sites. Increased reliance on road transport. Erosion of Ngāti Porou cultural identity.
Hydrological changes in rivers [Ecosystem performance]	Increased flooding (Frequency, volume, intensity)	Reduced ability of river channel to transport increased volumes of water. Loss of productive land.	Increased risk to life and property from flooding. Reduced quality and amenity of the local environment. Change in location of settlements (move to higher ground). Reduced ability to use river for transport.	Loss of life (historically). Damage to homes, and human settlements. Loss of asset/ capital. Damage to community and commercial facilities and structures. Damage to infrastructure and physical capital (bridges, roads, water supply intakes	Cost of repairs, insurances and relocation. Disruption to families and communities. Health & wellbeing effects. Strengthening of communities/ increased coherence and resilience. Cost to rate payer & taxpayer of infrastructure repairs or upgrades. Reduced incomes and material

				etc.). Damage to (or loss of) productive arable land and crops. Loss of historic sacred places. Reduced navigability.	wellbeing. Loss of cultural and social heritage or uses.
Water quality change (turbidity, nutrients etc) in rivers, streams [Pollution]	Reduced water quality. Risks to ecosystem productivity and diversity.	Disruption to biota and ecosystems (e.g. food web etc.). Reduced water potability. Reduction in fish and plant production waterways, estuaries and wetlands. Reduced quality of water for irrigation and production/ processing.	Health risks to individuals and communities. Reduced in-stream uses. Risks to stock and wildlife health. Effect on fisheries. Reduced agricultural production. Reduced food availability.	Reduced recreational opportunity – bathing. Reduced use of river for traditional activities – food preparation, bathing and laundry. Reduced farm incomes. Reduction in kai moana, and aquatic plant productivity & availability.	Reduced physical and mental wellbeing. Reduced engagement with river & environment. Illness. Cost of medical treatment. Cost of water treatment /alternative supply. Reduced aesthetic appreciation of water ways. Loss of culturally important food and food-gathering practises. Loss of self-sufficiency. Loss of cultural knowledge.
Increased river & stream bed load, sediment, debris	Increased movement and deposition on land and in waterways of debris (silt/mud/rocks/woody debris etc.) in floods. [pollution] Loss of habitat.	Impeding of river flow. Damage to river banks/flats and adjacent property. Increased availability of raw materials. Deposition of soil and nutrients on	Increased environmental risk. Increased damage infrastructure (bridges, water supplies, fences, irrigation systems etc.). Loss of wild foods (kapata kai). Changes in to quality and fertility of productive	Localised flooding. Costs of repairs and clean-up. Disruption to mobility. Increased availability construction & road building materials and firewood. Short-term decrease in food production and availability.	Cost to ratepayer & taxpayer. Loss of income. Reduced environmental amenity & enjoyment. Reduced cost of living. Inconvenience.

		productive land Pollution and siltation of wetlands, lakes and estuaries. Littering of coastal beaches.	soils. Loss of soil. Loss of crops. Reduced aesthetic appeal and quality of local environment.		

6.6.2 A framework to consider the economic aspects of erosion

Soil is a natural capital that is affected by natural and human influences. Accelerated soil erosion, where the rate of degradation exceeds the rate of soil formation serves to reduce this natural capital (McElwee, 1998, Dominati et al., 2010). Loss of soil in the Waiapu, as a result of erosion, has reduced the ability of the catchment to meet the community's aspirations and may consume resources that may be used to promote economic development or address other needs.

The cost of erosion may be understood in a number of ways. Krausse et al. (2001) describe the impacts of erosion as on-site (e.g. erosion) and off-site (e.g. sedimentation). Blaschke et al. (2008) expanded on this and outlined the impacts as on site erosion, sedimentation and flooding. A framework of the costs related to erosion are shown in Table 6.4, which give an indication of the numerous impacts which exist for the private individual and their assets, and for the public.

Table 6.4: Framework for economic costs of soil erosion (Adapted from Krausse et al. (2001)).

Effects		**Explanation**
Soil Erosion	Agricultural production loss	Reduction in pasture and crop productivity from soil loss
	Farm infrastructure loss	Cost of repairs to tracks, bridges and fences
	Direct private property damage	Loss to residential/industrial structures
	Road/rail infrastructure damage	Landslide erosion damage to road and rail network
	Utility network damage	Repair and maintenance of telephone and electricity network
	Recreational facility damage	Repair of walking tracks, huts, public facilities
	Loss of visual amenity	Aesthetic impact of slip scars
	Other soil erosion effects	Changes in farming confidence, damage to culturally significant sites
Sedimentation Reduced water quality	Consumption	Cost of filtering sediment from urban drinking water
	Processing	Filtering costs, loss of machinery efficiency, increased wear
	Recreation	Loss of fishing days, swimming, boating
Sediment	Water storage loss	Cost associated with lost storage in reservoirs and dams
	Navigation	Costs associated with sediment in ports
	Reticulation	Costs associated with sediment in irrigation canals, hydro canals and drainage ditches
	Biological degradation	Loss of aquatic life
	Other sediment effects	Dust nuisance, loss in community confidence
Flooding Increased flood severity	Insured loss	Flood costs covered by public or private insurance
	Production loss	Loss of production due to sedimentation on flood plain

6.6.3 Selected economic aspects of erosion for the Waiapu catchment

The following section considers economic aspects of erosion on the Waiapu catchment and the wider region. It draws on the framework above and provides illustrative examples in cases where information is readily available. It may be tempting to compare the cost of afforesting the remaining land in the Waiapu catchment for central government against the costs of erosion estimated below. However, this would be unrealistic for a number of reasons. The framework in Table 6.4 highlights the full extent of the potential costs of erosion in the Waiapu catchment, a full economic assessment accounting for the tangible and intangible costs of erosion would be necessary when comparing against the cost of projects to reduce erosion. Furthermore, the effects of climate change on the East Coast are likely to increase temperatures and reduce annual rainfall, with an increase in wind speeds and the frequency of intense rainfall events (Watt, et al., 2008), the exact impact of this on soil erosion is unknown, although erosion may be expected to increase with an increase in the frequency of intense rainfall events. Thus the associated costs may be expected to increase over time.

6.6.3.1 Pastoral production loss from erosion

The present value of lost pasture productivity due to slip erosion is estimated at $415,000 per annum in the Waiapu catchment. The value of lost pastoral productivity from slip erosion has been adapted from Krausse et al. (2001) to provide a Waiapu specific estimate. The methodology used here is the same as that of Krausse et al. (2001) except that (1) the area of potential erosion has been changed to the area of low producing grassland in the Waiapu catchment, (2) net cash income per hectare has been updated using recent MAF statistics (averaged from 2007/08-2010/11), and (3) an updated pasture recovery curve has been used, which better represents pasture recovery on the East Coast. The expected pasture production recovery curve for areas lost to slipping of Rosser & Ross (2011) has been transformed into a financial productivity curve using Gisborne Hill Country sheep and beef farming figures (MAF, 2011a) for net cash income per hectare ($566)[1]. The estimate for the net present value[2] of lost productivity caused by

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[1] Net cash income represents the economic surplus of the land however this is likely over estimated because MAF farm monitoring reports do include the opportunity cost of the land, e.g. land rental.

[2] Average discount rates typically used to estimate the market value of forests ranged from 7.1% for post-tax cashflows to 8.7% for pre-tax cashflows in 2011 (Manley, 2012), a rate of 8% was used for this analysis. Sensitivity of estimates to discount rates can be seen in the table below.

slip erosion[1] is $3340/ha eroded. The annual value of lost productivity is then estimated by applying the present value to the expected area of eroded pastoral land from slip erosion in the Waiapu catchment. This area is taken as the area of low producing grassland in the Waiapu catchment susceptible to erosion (47,950 ha)[2] multiplied by the annual expected area of eroded land (0.26%) derived from Forbes (Forbes, 1984). It is not possible to determine whether the slip erosion annually would be occurring on previously unaffected land or re-occurring on the same land. However, even after ten years this difference would be quite small, because a discount rate of eight percent would imply that approximately only a quarter of the NPV would be recovered in the subsequent seventy years.

There may also be downstream effects from loss of land upstream. Marden et al. (2011) points out that aggradation of the Waiapu riverbed will continue unless there is successful reforestation of active gullies. Aggradation may have a detrimental effect further downstream on more productive land, transport infrastructure, and buildings. It was not possible to estimate the damage cost on productive land, however estimates for avoided expenditure for the township of Ruatoria have been included below.

The value of lost pasture productivity due to surface erosion in the Waiapu catchment is estimated at $440,000 per annum. The value of lost pastoral productivity from surface erosion has been adapted from Krausse et al. (2001) updated with data on Gisborne hill country sheep and beef farming for gross cash income per hectare ($914)[3]. Unlike slip erosion the land is not taken out of production to recover slowly but rather reduces the soils capacity to provide support slowly over time. A 1% loss in productivity due to surface erosion, derived from Clough and Hicks (Clough & Hicks, 1992), is therefore applied to calculate the annual average lost pastoral productivity of $9.14 per hectare. The annual

6%	7%	8%	9%	10%
$500k	$450k	$415k	$385k	$360k

[1] Rosser and Ross (2011) estimate an approximate recovery of 80% after approximately 80 years. An 80 year period was forecasted because there is no guarantee of 100% recovery after this period.
[2] This figure is taken from Section 5.3.1.
[3] This does not take land out of production but rather reduces the productivity of the land by 1%, therefore the estimate for lost productivity per hectare will be relatively bigger than that of slip erosion because the farm revenue (gross cash income) estimate will be larger than net cash income used for lost productivity from slip erosion.

value of lost productivity is estimated by applying the annual average loss to the area of eroded pastoral land from surface erosion in the Waiapu catchment. This area is taken as the area of low producing grassland in the Waiapu catchment susceptible to erosion (47,950 ha).

6.6.3.2 Road/rail infrastructure damage

Damage to transport infrastructure affects the connectedness of a community and may have a negative impact on the economic viability of an area and the ability of individual enterprises to be competitive. The Waiapu is extremely reliant on State Highway 35 as the main arterial link between the East Coast and other regions. In 2008, Ruatoria was isolated for a week following a major slip which had a significant effect on the community. As a result the New Zealand Transport Agency realigned Busby‘s Hill to avoid a stretch of road vulnerable to floods and slips at a cost of approximately $3.5 million (NZTA, 2009). Estimates from the Gisborne District Council put the average annual expenditure on roads and bridges from storm damage at $200,000 but can reach as high as $500,000 in the Waiapu (Freeman, pers. comm. 2011).

6.6.3.3 Insured costs due to increased flood severity

Insurance payments for the East Coast after Cyclone Bola came to $43.9 million with almost half of this compensation ($20.6 million) going to hill country farmers (Parr, 1994). Using this *damage cost* to represent the scale of impact on the East Coast may be misleading as only 55% of properties of hill country pastoral farms (150 ha or over) claimed assistance. Furthermore, the insurance estimate only represents a subset, as not all qualified after claiming (Parr, 1994). The cost to hill country farmers from an event such as Cyclone Bola is likely to be much greater than this damage cost. No estimates are available for the Waiapu alone.

The issue of uptake of insurance highlights a key difficulty faced by the community. Although data was not available to determine which lands claimed insurance, a major constraint on Māori land structures is a lack of access to credit indicating a level of financial capital, which subsequently affects the option of insuring land. Potential reasons identified for this lack of access to credit are; multiple ownership of land, the cost of loan recovery, financial institution‘s perceptions of higher risk for land with trading restrictions, or a lack of knowledge of financial institutions (Kingi, 2008).

6.6.3.4 *Flood protection measures for Ruatoria*

The meandering of the Waiapu River and associated erosion of a terrace protecting the settlement has created a need for preventative works to safeguard the township (Freeman, pers. comm. 2012). Groynes have been installed over the last three years at a cost of $600,000 with a further of $50,000 expected in the fourth year. An average annual estimate of avoidance expenditure (avoided damage to Ruatoria township) over the four years of the project would therefore be approximately $162,500. This would vary over increased lengths of time as the need for such works is episodic as the river meanders.

6.6.3.5 *Public expenditure*

Other regional expenditure on erosion includes investment in education and advisory activities, and soil conservation and regulatory works. Estimates supplied by Gisborne District Council (Freeman, pers. comm. 2011) places expenditure on soil advisory/education activities for the entire region at approximately $440,000 per annum and regulatory works at approximately $149,000. As an estimate, 15% ($82,350) of these funds are spent in the Waiapu catchment.

6.6.3.6 *Central Government expenditure*

The ECFP has the sole aim of achieving sustainable land management through land use change on the 60,000 ha of severely eroding land. The project is not managed at a catchment scale which makes estimating the annual expenditure of the ECFP within the Waiapu extremely difficult. Total expenditure for the East Coast from the ECFP between 2007 and 2009 was between $1.7 and $2.2 million per year. For 2012/13, 100% of available funding has been allocated to forestry, wide-spaced pole planting and indigenous reversion projects – all to be completed by 30 June 2013 (R. Hambling, pers. comm. 2012). Under this scenario, annual expenditure is probably closer to the annual allocation amount of $4.1 million..

An indicative estimate of the total grant cost to central government to treat the remaining ECFP land in the Waiapu catchment would be in the region of $24 million. The cost of afforesting the remaining target land in the Waiapu (13,526 ha) is estimated by taking the current breakdown of average grant rates for each ECFP treatment on each land title (Māori or General) and the proportion of area treated based on the last three years (2009-2011) (Appendix 10). It should be noted that apportioning this across the remaining years of the ECFP would be unrealistic. This estimate does not include administration costs of the project.

6.7 Discussion: using conceptual frameworks to consider effects of erosion on people

The complexity and interconnectedness of social, economic, cultural and environment elements exhibited in the catchment clearly presents challenges. Not only when attempting to predict the possible impacts of future interventions, but also in just representing graphically the multiple impacts and directions of causality of observed past events. For example, Figure 6.8, below represents just some of the elements identified through this research project within the Waiapu that have arisen since the removal of mature forest cover over the last century.

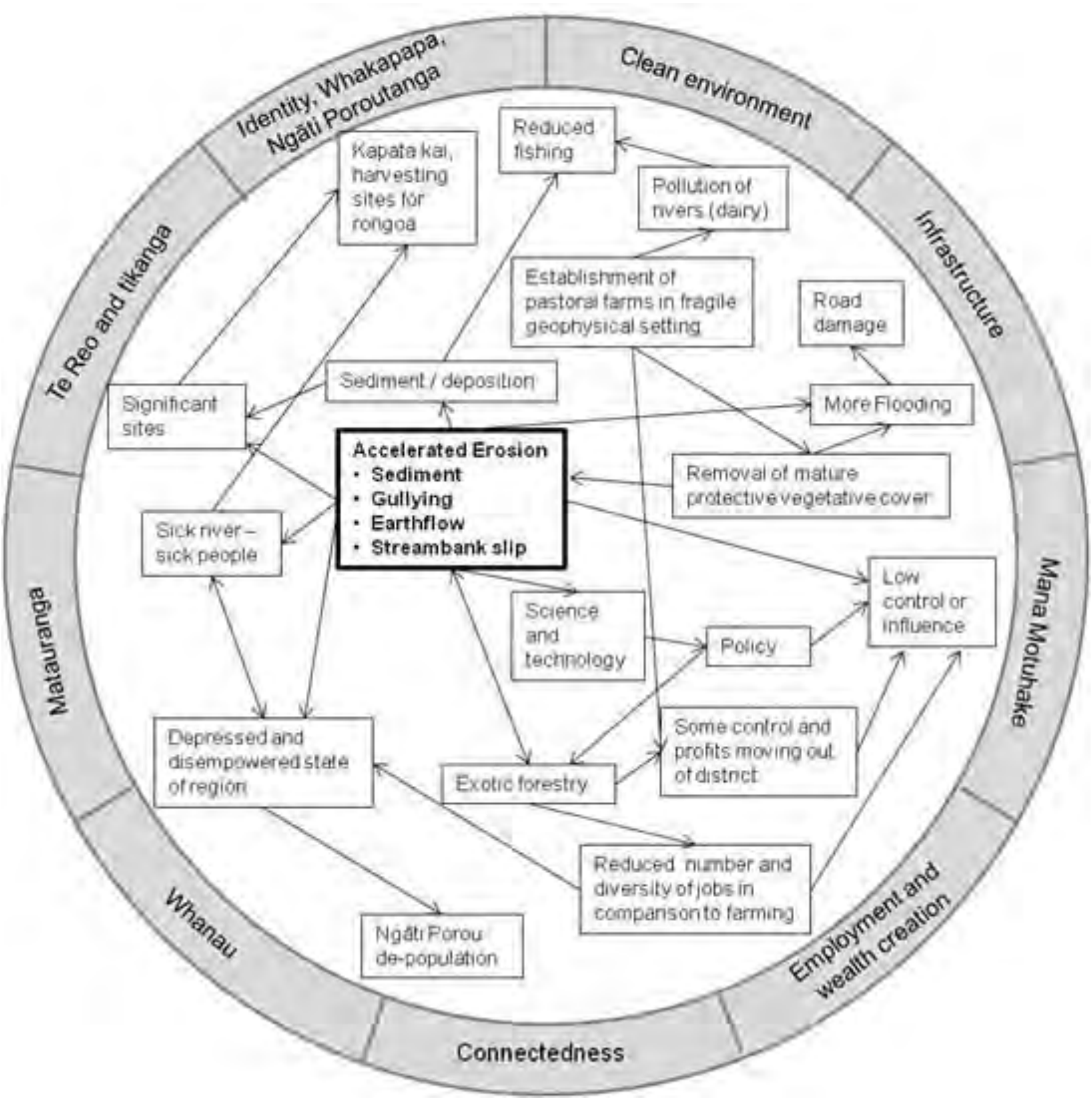

Figure 6.8: Web & chain diagram centred on accelerated erosion in the Waiapu catchment, within the aspirational framework for Ngāti Porou.

It was not possible within the limited scope of this study to develop a truly systematic approach to exploring and mapping the flows and relationships between the impacts (or shocks) that the catchment and its community have experienced. The diagram below (Figure 6.9), however, seeks to portray such shocks in a thematic way.

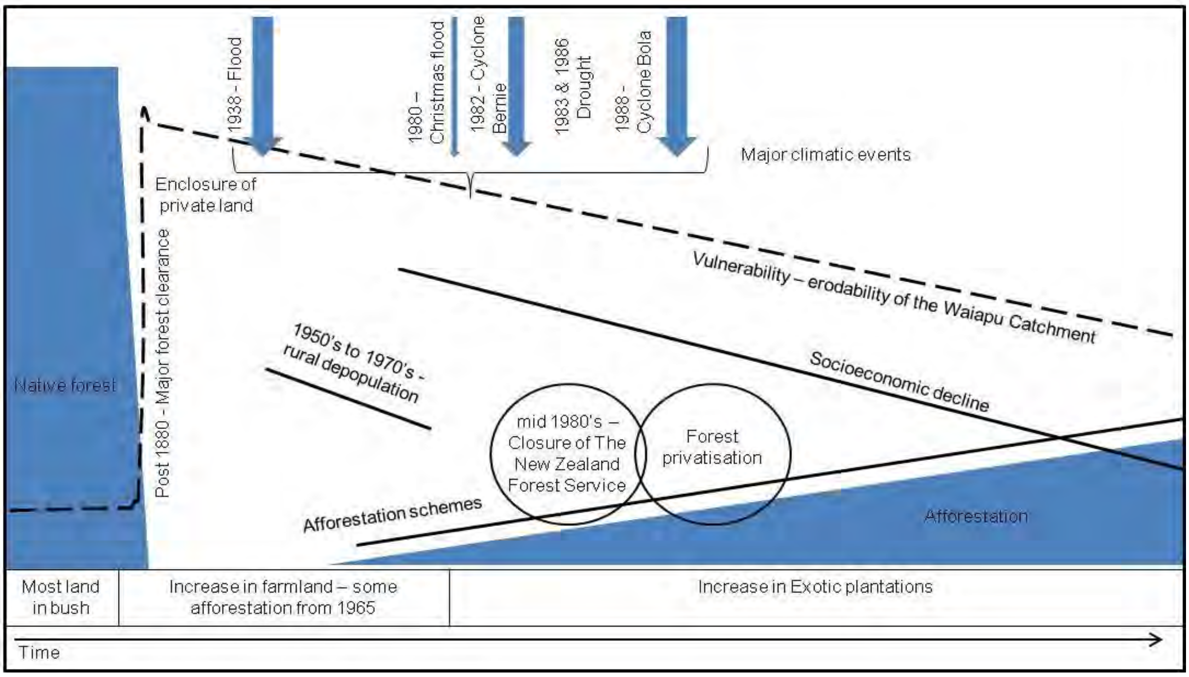

Figure 6.9: Social/economic and environmental shocks to the Waiapu catchment (Thematic diagram).

However, the importance of such frameworks, are well recognised in the social impact assessment literature, as such tools offer can be central in the efficient development and assessment of integrated interventions.

6.7.1 Integrating social and environmental models

Slootweg et al. (2001) offer a useful model to describe the relationship between human society and the biophysical environment, based on what they call a ‗function evaluation' of nature (see Figure 6.10). For Slootweg et al. (2001), the human world is depicted as generating ‗demands' on the biophysical world[1]. The demand for goods and services from the biophysical world is determined by what is considered valuable or important by

[1] Humans also generate significant demand for ‗services' from the human world itself – e.g. social attachment, knowledge transfer). That is, humans utilise one another‗s ‗human capital' (labour power, knowledge, etc), as well as the connections they have with others (social capital) to fulfill their needs & functions.

members of a particular group, for example the values expressed by the Ngāti Porou indicators. There is also a cautionary note that the weightings attached to these values, (which were not ascribed in this research) will vary between individuals, groups, wider society and are heavily shaped by worldviews and culture. Differing interpretations of the weightings attached to values may often be at the root of disagreements or debate over priorities and the design of interventions. The authors note three categories of human values which are all present in the Ngāti Porou framework described earlier:

- Social values, that is those things that contribute to the quality of human life (for livelihoods, wellbeing, etc) in a particular society/culture,
- Economic value, that is, the monetary or exchange value assigned to goods and services provided by the environment (resources, income etc) in a particular society/culture,
- Ecological values, that is, the value put on the maintenance of ‗the earth's life support systems', both over time (in the future) and space (e.g. for ecosystem and environmental functions elsewhere).

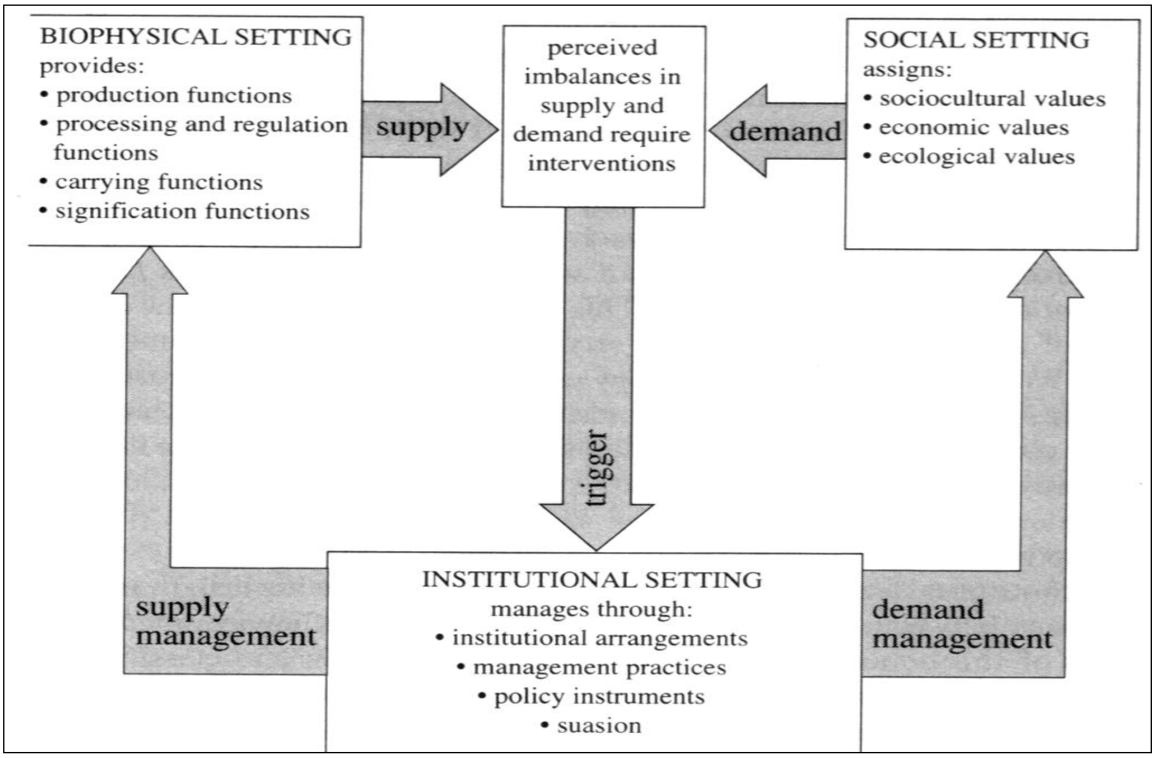

Figure 6.10: Main setting in function evaluation (Slootweg et al., 2001, p20).

6.7.1.1 Supply side

In the model (Figure 6.10) the natural and modified biophysical natural world/setting supplies various functions important to humans, including:

- Production functions, which ―relate to the ability of the natural environment to generate useful products for humanity”, including renewal and non-renewal resources;
- Processing and regulation functions which ―relate to the maintenance of ecosystem support services” (e.g. life support, maintenance of biodiversity, maintenance of ground water levels, carbon sequestration, coastal protection, etc);
- Carrying functions, which relate ”to space or to a substrate that is suitable for certain activities and for which there is a demand” (e.g. space suitable for human settlement/agriculture etc, waterways for electricity generation); and,
- Signification functions, that is as a ‗host‘ or subject of ascribed human values, including ‗natural heritage values‘ and ‗cultural heritage values‘. Here the biophysical world serves as the basis for human aesthetic, religious, psychological, historic, cultural, artistic, educational, and scientific information and experiences.

As can be seen in the model (Figure 6.10), Slootweg et al. (2001) argue that human-perceived imbalances of supply and demand give rise to a call within society for intervention – which can be responded to by attempting to manage the supply of the biophysical ‗functions‘ and/or attempting to manage the human demand on these functions.

For example, Table 6.5 shows two socio-cultural elements from the Ngāti Porou and Slootweg frameworks combined together. They serve as an example of how the framework may be used to further develop understandings and the possible design of future options. These aspirations relate to food production and employment in the region. Notes on the extent to which the environmental setting can support the desired functions are plotted under the relevant supply side heading.

Table 6.5: Ngāti Porou criteria set within a conceptual Function Evaluation framework that integrates community aspirations with biophysical states.

Demand Side		Supply Side			
Slootweg model category	**Ngāti Porou**	**Production Functions [*of useful products for humanity*]**	**Processing and Regulation Functions [*maintenance of ecosystem services*]**	**Carrying Functions [*ability to accommodate human demands – habitation*]**	**Significance Functions [*as a host for ascribed human aesthetic and spiritual values*]**
Socio-cultural values	***Ngāti Porou are never hungry and can feed themselves and their whanau from the land.***	Strong evidence of decline in traditional food sources and degradation of productive land (Maara) to support the community.	An area of significant mismatch. Resources diminished by inability of environment to recover from shocks – erosion, forest clearance and extreme weather events.	Considerable reduction in carrying capacity.	‗If the river is sick the people are sick'. Inability of the land to support Ngāti Porou presumably reflects symbiotically and negatively on Ngāti Porou.
	All Ngāti Porou have a job opportunity in the Waiapu catchment.	Diversity of products (and employment opportunities) from catchment has decreased for a variety of reasons including inappropriate decisions over land use and a decline in environmental quality. More local economic activity needed (e.g. Manuka honey) to provide a range of locally owned businesses and jobs	Resources needed to support economic activity, and employment generation, are diminished by an inability of the environment to recover from shocks – erosion, introduction of exotic and pest species, forest clearance and extreme weather events.	Erosion increases damage to infrastructure and the costs associated with establishing and maintaining employment generating activity.	The creation of job opportunities for Ngāti Porou within the catchment is closely linked to cultural identity and the restoration of the relationship of the people to the land and the river, including the return of Ngāti Porou who have left the region. Lack of employment opportunities, leading to no in-migration of Ngāti Porou, poverty, and continued out-migration further undermines cultural identity.

NB. This table serves only as an example of the potential use of the framework. The contents are extrapolated from the literature review.

A possible future research direction for the community would be to use their values/indicator framework to explore their own interpretation of the demand/supply table above. Interventions may then be developed from an analysis of the mismatches between demand and supply identified in the framework.

6.7.1.2 Interventions, changes and the integrated assessment of impacts

Figure 6.11 outlines Slootweg's logical procedure for identifying the biophysical and human impacts of (bio)physical changes. An important feature of this general procedure is the distinction made between the observed or potential changes and the impacts of those changes, both in terms of biophysical functions and social values. That is, it notes that ‗changes' are not the same thing as ‗impacts', with a change only becoming an impact when it is socially significant (in terms of values).

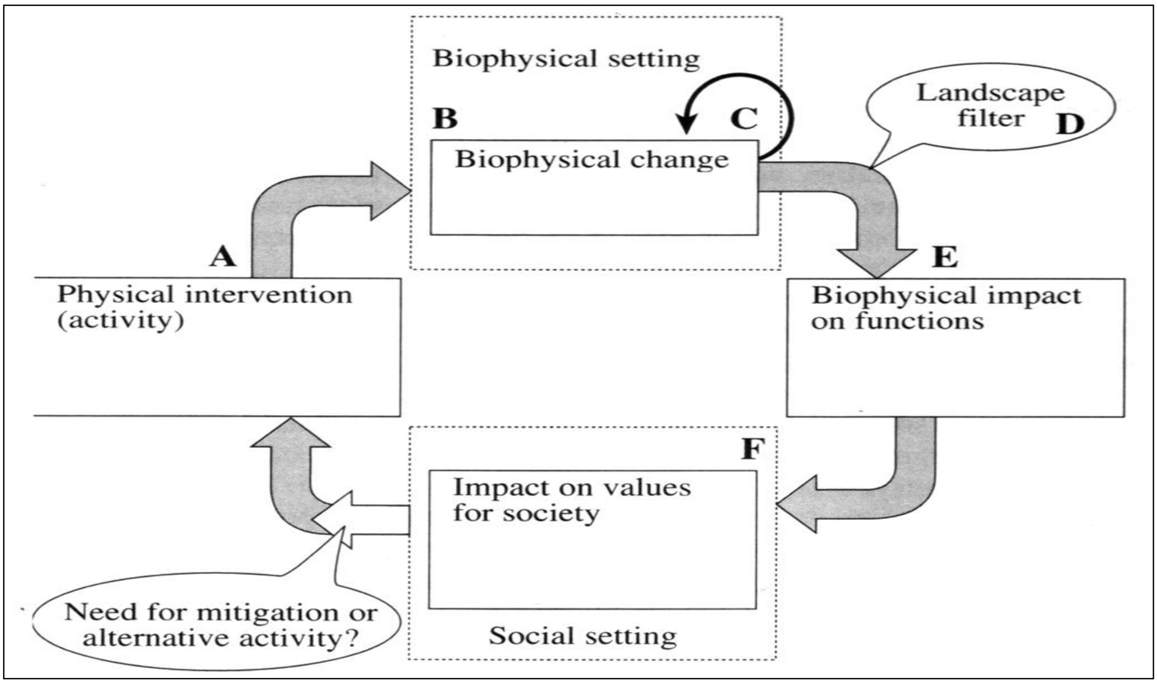

Figure 6.11: Function evaluation of settings (From Slootweg et al., 2001, p23).

Slootweg et al. (2001) have combined their conceptual model with the impact assessment framework into a model of the pathways to derive biophysical and human impacts (Figure 6.12).

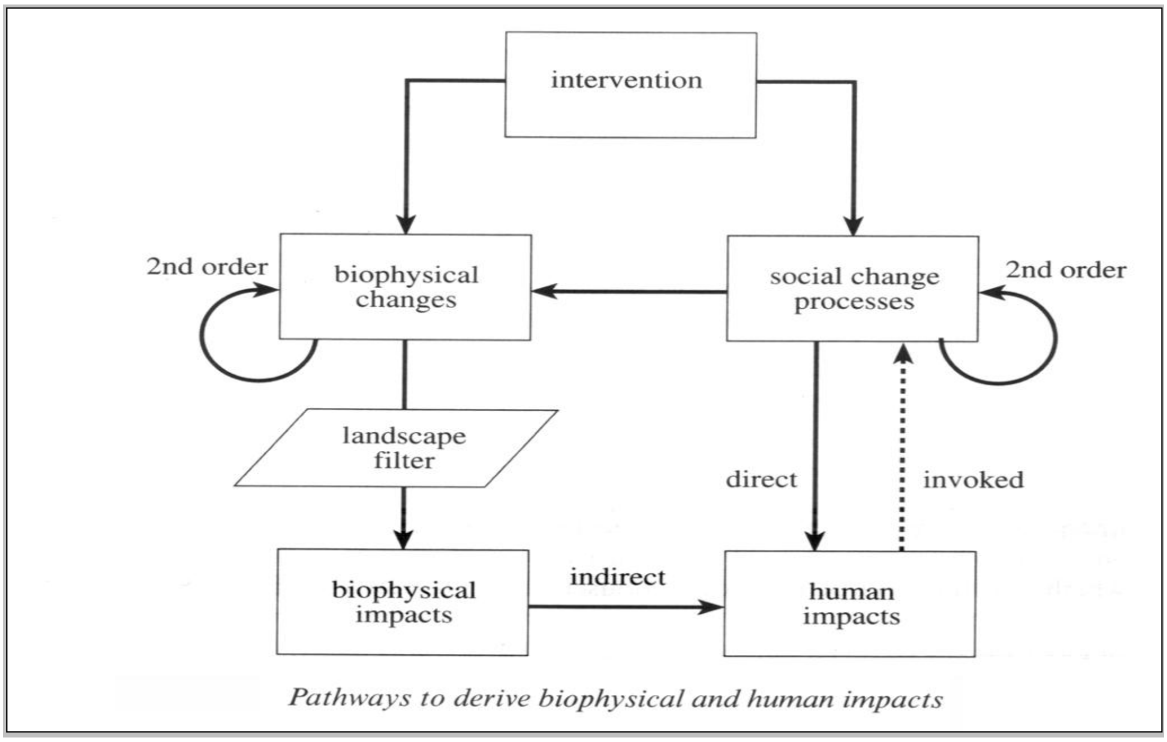

Figure 6.12: Pathways to derive biophysical and human impacts (From Slootweg et al., 2001, p26).

It can be implied from Slootweg et al. (2001) attempt to provide a method to map the pathways of biophysical and human interactions that all impacts ultimately have human consequences. Indeed, our interest in the biophysical world must (and can only be) self- serving since we can only see the world though human eyes (despite efforts to do otherwise). This ‗self-interest‘ or concern can range from wanting to sustain our livelihoods by protecting the productive value of the land through to wanting to enhance or protect the temporal ecological value of species that we have little direct interaction with (e.g. to protect the existence, cultural, spiritual or even potential but unrecognised social value of a species or ecosystem for future generations). That all impacts are ultimately human/social is reinforced by our increasing recognition that human activity or ‗intervention‘ in the biophysical environment can have serious consequences (and costs) for us and our society. Likewise, changes in the social/human world (e.g. in quality of life expectations) may lead to changes in the biophysical environment - the consequences of which tend to feedback as impacts on ourselves.

6.7.2 Next steps

6.7.2.1 Designing interventions

As with the original clearing of forest to create pastoral farms in order to create wealth and familial livelihoods for non-Māori settlers, interventions to reduce the erosion and its effects can also have undesirable as well as the desirable socio-economic and cultural effects/impacts.

Future proposed catchment management policies or erosion control programmes will therefore require careful environmental and social impact assessment and be informed by the perspectives, values, and experiences of the tangata whenua.

6.7.2.2 *Challenges for assessing the human/social impacts of changes in the biophysical environment*

In addition to understanding the relationship (cause and effect) links between the biophysical world and the human/social world, assessing the human impacts of erosion presents a number of methodological challenges. These include questions of

- how to attribute impacts to causes in dynamic situations; and,
- how to deal with cumulative impacts.

Both situations (multiple sources of change, and cumulative impacts) present problems for those seeking to attribute particular changes and costs to particular causes.

6.7.2.3 *Attributing impacts to particular causes in complex and dynamic systems*

Separating out the social impacts of erosion in the Waiapu catchment from those arising from other social and biophysical changes can be problematic in dynamic situations and systems (the ‗attribution problem'[11]). For example, the productivity of a farm expressed as income can be simultaneously affected by, among other things, climate, the farm inputs and their cost (e.g. timely use of water and labour, the quality of the base stock, application of fertilisers), pest numbers, the international market, and the state of farm and district infrastructure.

The sustainability of farming can be influenced by these factors, as well as, for example, by the regulatory environment, the state of the local community and landownership arrangements. The larger the geographical unit of analysis, and the longer the timeframe, the greater chance there is of multiple or cumulative sources of change leading to human impacts, and the more difficult it becomes to attribute particular amounts of impact/cost to particular causes.

6.7.2.4 *Cumulative change and impacts*

This presents a complementary challenge in impact assessment. Cumulative impacts are those that result from interactions of many incremental activities, which may have varying (positive

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[11] This also applies to the evaluation of the actual impacts or outcome of an intervention.

and negative) effects on their own but become more significant or more complex when aggregated or when they coincide with each other – including synergistic effects (Hunsaker, 1998). In the case of deterioration in biophysical and social conditions in the Waiapu catchment area, the impacts may arise from:

- The overlapping of the effects of extreme climate events with the effects of social or economic changes, for example changes in market conditions, loss of subsidies or incentives.
- The overlapping of either situation with interventions aimed at reducing individual erosion or its social and economic impacts.

Such effects may appear quickly or after considerable delay; may be additive, subtractive, or synergistic; or may appear in different human domains or at different levels of social organisation. To use the ripple analogy, a series of overlapping waves of impacts can amplify effects that might otherwise be minor if caused by a single effect (climate event, source of social policy change, or intervention).

Simultaneous or sequential interventions to reduce erosion and/or reduce its impacts may also unintentionally cancel out desired social effects, or result in significant unintended outcomes. Unanticipated effects can become more likely when there are many potential types of overlapping interventions.

This challenge has practical implications for intervention design. The complexity of impact patterns provides a rich basis for the construction of legal defences for actions which have been clearly detrimental. Inability to identify the exact point of impacts, or extent of impacts attributable, means that nil effect cannot be ruled out, and this understandably forms the starting point for those commissioned to minimise remedial costs. Insidious, multi-causal damage to the health of the environment is therefore difficult to address in full at source through user-pays mechanisms/clean up costs. Interventions are therefore more effective when placed upstream in the form of prudent avoidance as part of the institutional setting.

6.7.2.5 How to deal with „orders' of social impacts

The notion of cumulative impacts is related to that of the ‗chain of effects'. In theory it is possible, either though a mechanistic or systems analysis, to describe the chain of effects, including social effects, that result from biophysical changes resulting from land use change (e.g. forest clearance) or an extreme event. These chains are sometimes depicted as schematic, tree diagrams, networks, or ripple diagrams.

Impact assessors refer to these as ‗orders‘ of effects, e.g. 1^{st} order, 2^{nd} order, 3^{rd} order etc, or as ‗direct‘, ‗indirect‘ and ‗induced‘ effects (Taylor et al., 2004; Porter, 1995). At each new level in the tree of cause and effect the number of possible effects and impact domains (and therefore complexity) increases dramatically, depending on what we know from research and experience about cause and effect links. Researchers therefore have to make pragmatic decisions about how far to extend their analysis before the effects become trivial or the outcomes become clearly unattributable to the original land use change/erosion event (or the erosion control intervention). Figuratively, and literally in the case of erosion control, interventions made upstream have more impact(s).

6.8 Governance processes, management and engagement: aims and models

There are forested areas in many parts of the world where the predominant resident population is indigenous/first nation/aboriginal.

Common characteristics of these areas include:

- Marginal pastoral value and/or degraded state of biodiversity,
- Loss of social carrying capacity through environmental damage including soil erosion and sedimentation,
- Low socio economic status of resident populations,
- Uni-cultural approach to planning and development that underemphasises alternative value sets,
- Centralised development that does provide the necessary autonomy and means to make and implement policies that reflect the interests of local people,
- Outdated allegiances to short-term economic development initiatives that focus almost exclusively on large-scale endeavours, often at the expense of other, perhaps more sustainable, economic development opportunities,
- A need for safeguarding the well-being of communities through economic diversification and securing of the necessary investment in local institutions and infrastructure.

In the last 15 years constructive efforts have been made in Canada, India, South America and a number of other regions to improve the health and wellbeing of the environments and resident populations. Strategies have typically centred on: building and utilising more comprehensive understanding of locally held values and aspirations; the use of collaboratively constructed indicator frameworks to measure status and progress; and extended co-governance models that move beyond the usual local consultation steps in recognition of the special position of the indigenous peoples.

Successes are reported (Stevenson & Natcher 2009). A valuable next step would be to systematically review the approaches, methodologies and long term outcomes of the more durable and productive of these overseas initiatives and investigate how the lessons learned there might be applicable in the Waiapu context where a self-improving forest management system responsive to the values, expectations, and changing needs of community members is clearly needed.

6.9 Summary & conclusions

The work presented in this chapter draws on currently available published literature and unpublished data that was sourced or collected within the project time-span to identify issues related to erosion and the wellbeing of Ngāti Porou. Through this research we have developed a bi-cultural framework of criteria and indicators which, when taken together, describe a ‗desired state‘ and which may be used to describe key past and current data of relevance, and assess progress toward a desired state in the current environment (including policy and mitigation efforts to date). This framework of criteria and indicators was developed by invited members of Ngāti Porou with the project team. It is acknowledged by the project team that further consultation is required with Ngāti Porou on the indicator set. Apparent gaps in the available data are identified and conceptual approaches to linking environmental and social data together to inform future policy interventions are introduced.

In summary:

- This chapter and the supporting literature review (Chapter 3) draw from a pool of around 30 documents dating back to the 1891 census, but predominantly on a small number of key works most of which were produced within the last ten years and are largely ethnographic in nature.
- Supplementary data on criteria and indicators of a Ngāti Porou ‗desired state‘ were gathered and compiled specifically for this study in late 2011.
- The literature presents a picture of a fragile landscape with its ability to support the needs and aspirations of Ngāti Porou greatly reduced over a century and a half.
- A socio-economic profile of Ngāti Porou in the Waiapu catchment outlining the state of community wellbeing is presented. According to the 2006 Deprivation Index, the East Coast area (and Gisborne District) is one of the most socio-economically deprived areas in the country. This has been the case since deprivation indices were attempted in the 1980‘s.

- Within the district, the people of Waiapu catchment, especially those resident in the northern part (i.e. lower end of the river), are among the 10% most deprived people in the nation. In short, the residents of the Waiapu catchment are especially poor by New Zealand standards — both materially and in access to opportunity.
- Prior to Cyclone Bola the Waiapu area was already disadvantaged. The situation was made worse after 1985 (before Cyclone Bola) when the Government corporatised (and later privatised) the New Zealand Forest Service.
- A major strength of this research is that it presents a valuable Ngāti Porou worldview, and also an East Coast perspective on the multiple causes and diverse long-term impacts of erosion on communities and their aspirations.
- A repeated theme in the literature and this chapter of the report is the view expressed by many Ngāti Porou that erosion is not an isolated problem and that integrated approaches are required to tackle the many problems the catchment faces. Future strategies should embrace Ngāti Porou values and aspirations fully.

The major social, economic, and cultural impacts (reflecting the size and scale) of the erosion problem in the catchment may be summarised as follows:

- Flood, sediment, and erosion damage to stocks and flows of critical natural capital compromises the ability of local people to meet their needs, especially with respect to abundant good quality seasonal food, fresh clean water, and other resources.
- Degradation and loss of natural capital within the catchment is likely to have contributed to on-going rural depopulation and a loss of human and social capital, with associated reduced community functioning, strength, reduced wellbeing, reduced cultural identity and expression, loss of services, and economic marginalisation.
- High levels of social and economic deprivation which are not helped by a degraded landscape and eroded natural capital.
- A dependency and reliance on external intervention to address the problem at the catchment/landscape level.
- An awareness of a reduced connection between the people and the whenua (river, forest, and natural world) and each other, resulting in reduced physical and spiritual wellbeing.
- A loss of general and specialist knowledge of the environment and cultural practices associated with catchment-based livelihoods over time as a result of landscape change and the loss of a traditional resource base.
- A loss of economic development opportunities and options as a result of a degraded landscape.

- Direct damage to houses, infrastructure, and productive land from increasingly frequent and voluminous floods.
- A lack of engagement in catchment management, decision making, and planning is perceived to be preventing the community from pursuing its own vision of a desired state for the Waiapu catchment and hindering community engagement in the resolution of the problem.
- Loss of soil from the Waiapu catchment, as a result of erosion, has reduced the ability of the catchment to meet community needs; consuming resources that may be used to support economic development.
- The present value of lost pasture productivity due to slip erosion is estimated at $415,000 per annum in the Waiapu catchment.
- The value of lost pasture productivity due to surface erosion in the Waiapu catchment is estimated at $440,000 per annum.
- The Waiapu catchment faces many other costs as a result of soil erosion, through damage to infrastructure, insurance costs, recreational loss, and biological degradation. Some can be estimated but further research is needed to determine the full economic impact from soil erosion in the Waiapu.
- An indicative estimate of the total cost to central government to treat the remaining ECFP land in the Waiapu catchment would be in the region of $24 million.
- The ECFP and LO3A do not have explicit social, economic, and cultural objectives. The number of indicators developed by Ngāti Porou through this research and their breadth in terms of the issues they raise would suggest that the challenges facing the catchment and its people are many and only a very small number of these are being addressed by current efforts.

The conclusions based on this chapter of the report are:

- The catchment and the people who depend on its resources have been subjected to a series of environmental, social, and economic shocks for over a century. These shocks have had impacts on the wellbeing of Ngāti Porou in the catchment and appear to have played a contributory role in the current low socio-economic profile for the area and a degradation of cultural values of importance to Ngāti Porou.
- Interventions to date, based on this brief and provisional assessment, have not fully addressed or embraced the aspirations of Ngāti Porou as far as can be assessed or reflected in their holistic view of the interconnectedness of the wellbeing of the community and environment — that the health of the river and the people are one.
- In defining future courses of action and interventions to reduce the erosion and its effects, it should be recognised that they may lead to undesirable as well as desirable

socio-economic and cultural impacts. Future proposed catchment management policies or erosion control programmes will therefore require careful environmental and social impact assessment and be informed by the perspectives, values, and experiences of Ngāti Porou.

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7 Toward a desired state for the Waiapu River & catchment

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7.1 Introduction

In this chapter we make comment on possible options to control erosion in order to move toward addressing aspects of a desired state for the catchment. It is beyond the scope of the present study to consider options for addressing all aspects of a desired state. All possible options considered here involve the revegetation of eroding and erosion-prone land (with afforestation as the default approach) and differ primarily in terms of the definitions applied to the land targeted for treatment. The options are remedial in nature and are aimed specifically at helping to arrest the erosion of land and the associated sediment generation in the catchment. Comment on the land use change implications of, and potential issues and opportunities around, the various approaches to the revegetation of eroding and erosion-prone land is also made. It is important to note here that our ability to identify the amount, mix, and spatial distribution of the various erosion mitigation measures (afforestation, reversion, and wide-spaced tree planting) required to improve geophysical conditions of the catchment sufficient to address aspects of a desired state is limited by the knowledge gaps identified in Section 2.12. More specifically, how much afforestation, reversion, and wide-spaced tree planting is required to affect a switch from aggradation to incision and how long it will take for the effects to manifest in the main stem of the Waiapu River are unanswered questions.

It is important to acknowledge the complexity of the task seeking to restore the Waiapu catchment to a desired state and that any option or intervention to address the erosion problem may have both positive and adverse effects. It was noted in Chapter 6 that:

> In defining future courses of action and interventions to reduce the erosion and its effects, it should be recognised that they may lead to undesirable as well as the desirable socio-economic and cultural effects/impacts. Future proposed catchment management policies or erosion control programmes will therefore require careful environmental and social impact assessment and be informed by the perspectives, values, and experiences of Ngāti Porou.”

We fully acknowledge that for Ngāti Porou, the health of the river and the health of the people are the same and that any attempt to address erosion should be developed with Ngāti Porou and local communities and fully consider the direct, indirect, and induced effects on the aspirations and wellbeing of the people. For this reason, it is not our intension to prescribe or dictate solutions but rather to suggest possible options – based around current knowledge of the catchment – as starting-points for further consideration and development of solutions with Ngāti Porou and the local communities. Action is required to avoid further deterioration of the river and catchment from its current state — based on the modelling of Herzig et al. (2011), afforestation of at least all existing gullies by 2020 is required keep gully sediment yields near current levels (22 Mt/yr) by 2050. However, a key message that emerged during the course of this study is that any attempt to develop and implement interventions to address the erosion problem in the Waiapu catchment without the direct and active participation of Ngāti Porou (as mana whenua) and local communities is unlikely to be successful.

7.2 A desired state for the Waiapu River & catchment

A desired state for the Waiapu River and catchment as expressed during the consultation with Ngāti Porou undertaken as part of this study and documented by Tina Porou (see Section 6.4) is repeated here for ease of reference.

“Ngāti Porou have identified that they desire a river that is clean, has drinkable water, and flows freely — a river where Ngāti Porou can swim, play, and enjoy the waters safely to contribute to the re-invigoration of the relationship between the people and the environment. They envisage a future in which they have control over the river and its catchment as kaitiaki and have the ability to decide and influence the protection and sustainable use of the Waiapu, and through this influence they could reduce the sources of pollution to the awa and use matauranga that was honoured, respected, and relevant to restore the catchment.

Ngāti Porou want a river that is again a kapata kai, bountiful with flora and fauna to sustain Ngāti Porou and, in turn, for Ngāti Porou to sustain the river. They desire a future in which Ngāti Porou again understand the intimate relationship that the people once had with the River and, *through this improved understanding, take greater responsibility for their land use choices and how they affect the Waiapu, and create economic opportunity through innovation and sustainability to improve the lives and incomes of Ngāti Porou people. They wish to see indigenous forestry restored to the Coast to slow the erosion which eats at the land and to ensure the protection of those areas of natural forest that remain.*

Ngāti Porou want to restore the economic independence of its people through the reinvigoration of the export of food stuffs from the East Coast and via the Waiapu, similar to the work of Mokena Kohere in the late 19th century.

Finally Ngāti Porou want to ensure that they do not pass the River onto future generations in a state worse than its current state — ***to at the very least****, do no further harm to the River and its catchment."*

7.2.1 Summary of the key elements of the desired state

With respect to the Waiapu River and its catchment, members of Ngāti Porou have identified that they desire:

- Improved water quality and condition of the Waiapu River to:
  - Enable the river to once again be used as a source of abundant food, drinking water, and for recreation.
  - Contribute to the re-invigoration of the relationship between Ngāti Porou and the environment through an ability to interact more closely with the river.
- Restoration of the intimate relationship between Ngāti Porou and the river to:
  - Enable greater responsibility for land use choices and the impacts of these on the river.
  - Create economic opportunity through innovation and sustainable use of the resources of the catchment.
  - To ensure that future generations sustain and feed the connection between the people and the river.
  - To record and pass on oral history and matauranga connected with the river.
- Rangatiratanga over the river and catchment as kaitiaki with the ability to decide and influence the protection and sustainable use of the river through the use of matauranga.
- The protection of existing natural forest and the restoration of natural forests within the catchment to slow the erosion.
- Restoration of economic independence through the re-invigoration of sustainable economic opportunities based in the catchment.
- At least no further deterioration of the river and catchment from its current state.

Although a timeframe around achieving the desired state was not explicitly expressed during the consultation process, a comment was made by a participant at one of the hui that suggests that there is an expectation, at least among some, that the desired state will take ‗generations' to achieve (T. Porou, pers. comm.)

7.3 Assessment of achievability of controlling erosion in the context of a desired state

Three of the six elements of the desired state identified in the previous section (improved water quality and river condition, protection and restoration of natural forests, and no further deterioration of the river and catchment) are, in some way, directly related to the geophysically and ecologically degraded condition of the catchment at present. Here, we are commenting in general terms on the extent to which a desired state (where erosion is controlled or greatly reduced) may be geophysically or practically achievable given the profound changes in landscape morphology and behaviour that have occurred within the catchment since wide-spread deforestation. It is important to recognise that the environmental processes (i.e. erosion) currently at work in the catchment are the result of a social change process (forest clearance) which is now having a major impact on Ngāti Porou and the capacity of the community to sustain itself.

7.3.1 Improved water quality & river condition

The present degraded geophysical state of the Waiapu catchment is a result of erosion triggered by deforestation, and the subsequent redistribution of sediment throughout the landscape and river system. The use of woody vegetation – targeted afforestation, reversion, and well-designed and maintained wide-spaced tree planting in particular – have all been shown to be successful methods of mitigating erosion in this landscape. Therefore, we know in general ―what works and where" to potentially move toward addressing erosion-related aspects of a desired state. The unanswered questions are: (1) exactly how much afforestation, reversion, and wide-spaced tree planting is required and (2) how long will it take before the benefits of these actions become apparent or are manifest throughout the catchment? Both questions are relevant to the achievability of the desired state from the geophysical or practical point of view.

There are no similar catchment-scale examples in New Zealand that we can use to inform us and assist in answering the questions posed above. However, we do know that the erosion response to both deforestation (gully initiation and river aggradation), and afforestation (gully stabilisation and river incision in headwater reaches) within the Waiapu catchment has been rapid — in the order of ~20-30 years. Undertaking further modelling studies is one possible way forward in terms of seeking answers, but this would require some new data. There are overseas examples in similar terrains with similar deforestation/afforestation cycles that provide analogies for the lag time in river response from aggradation to incision. In the Southern French Pre-Alps a similar cycle of afforestation/deforestation has taken place, except that deforestation and afforestation both commenced about 100 years earlier (1790 and 1860) than in the Waiapu catchment (Table 7.1), and widespread channel incision in response to afforestation is now well advanced (Figure 7.1) (Liébault et al., 2005).

Table 7.1. Comparison of physical conditions and land use history between Gisborne-East Coast region and Southern French Pre-Alps.

	Gisborne-East Coast region	Southern French Pre-Alps
Elevation range (m)	0-1,750	150-2,000
Mean annual rainfall (mm)	1,000-4,000	750-1,100
Geology	Cretaceous-Pliocene greywacke, mudstone, argillite and sandstone.	Jurassic-Cretaceous black marl, limestone, marly limestone and sandstone.
Vegetation	Exotic and natural forest, scrub, and pasture.	Exotic and natural forest, scrub, and ploughed lands.
Forest cover (%)	~29	~70
Land use history	First human-induced forest clearance: 700 yr BP (Māori settlement). Last period of accelerated deforestation: 1880-1920 (European settlement). Last afforestation period: 1960's-present (erosion control and commercial forestry).	First human-induced forest clearance: 6000 yr BP (Neolithic settlement). Last period of accelerated deforestation: 1790-1850 (high demographic pressure and privilege abolition following the French Revolution). Last afforestation period: 1860-1910 (erosion control) and 1945-present (natural afforestation following rural depopulation).

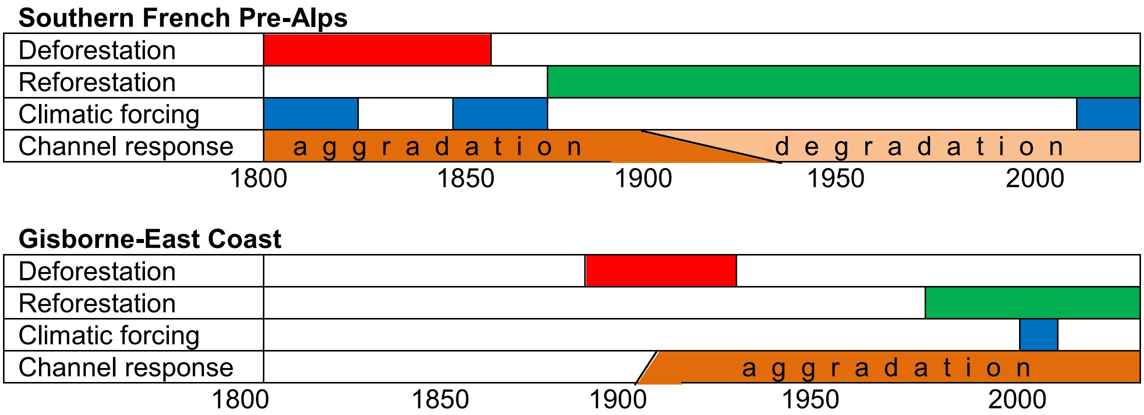

Figure 7.1. Generalised chronology of land use change, climatic forcing, and channel response (lighter shading denotes an attenuation of the response through time) in the Southern Pre-Alps and the Gisborne-East Coast. Climatic forcing refers to periods or events with extreme rainfall (after Liébault et al., 2005).

Similarly, the Arno River in central Italy was aggrading prior to about 1845, after which afforestation of the headwaters took place causing a reduction in sediment supply, and by the beginning of the 20th century the main channel had begun to incise by 0.5 to 2 m (Simon & Rinaldi, 2006). Madej (1995) and Madej & Ozaki (1996) have reported a similar channel aggradation-incision cycle in the 50 years following logging of the Redwood Creek catchment in north-western California. They expect channel recovery and restoration of aquatic and riparian habitats to take several decades to a century, based on existing channel-bed elevations, pool-riffle development, and sediment yields. In the Ringarooma catchment in Tasmania, 110 years of tin mining activity has also resulted in aggradation and subsequent incision of the river. Here, upper reaches have regained their former level in about 35 years after mining ceased, while complete flushing of sediment from the river is expected to take at least another 50 years (Knighton, 1989). In the Waiapu catchment, despite sediment yields that are much greater, a number of headwater streams, where afforestation of their catchments has occurred, have begun to incise. Recovery of the Weraamaia Stream, based on current rates, is expected to take several decades (Kasai et al., 2005). However, the lower reaches of the Waiapu River are currently still aggrading.

The examples described above suggest that improvements to the current geophysical state of the Waiapu catchment – and consequently movement toward achieving some elements of the desired state – may be achieved over multiple decades to a century through the further establishment of woody vegetation (i.e. targeted afforestation, reversion, and well-designed and maintained wide-spaced tree planting) in appropriate parts of the catchment. However, every catchment is different, each has a unique assemblage of landforms with different evolutionary histories, and the way that water and sediment are passed through this configuration of landforms is difficult to predict (Page et al., 2008). For these reasons, and given the current state of knowledge, only very broad statements can be made about the amount of afforestation or land use change required to achieve or approach the desired state and how long this will take.

7.3.2 Protection & restoration of natural forests

Under the Deed of Settlement between Ngāti Porou and the Crown, a strategic partnership was agreed to that will involve the co-authorship of a separate section of the East Coast/Bay of Plenty conservation management strategy. This section of the conservation management strategy, to be known as nga Whakahaere Takirua mo nga Paanga Whenua o Ngāti Porou (―nga Whakahaere Takirua"), will set the policy and planning framework for management of the natural and historic resources of nga Paanga Whenua o Ngāti Porou. Also, the Department of Conservation presently administers ‗Nga Whenua Rahui' established to protect, via a 25-year covenant, natural ecosystems on Māori land that represent a full range of natural diversity present in the landscape. Many existing areas of natural forest within the Waiapu catchment could be protected via this mechanism.

Issues relating to the establishment of indigenous forests, such as establishment methods, costs, and carbon benefits, were examined in a report by Davis et al. (2009). In comparison with the establishment of exotic forests, experience in the establishment of indigenous forests, particularly over large areas, is much less and there are knowledge gaps around performance, establishment methods, and costs (Davis et al., 2009). At least in the short-term, large scale artificial re-establishment of natural forests to control erosion is unlikely to be practicable due to issues of supply (G. Steward, pers. comm.) and cost of nursery-raised seedlings. However, a mixed treatment strategy that could be financially and practically possible might involve:

- Natural regeneration of indigenous species such as manuka and kanuka,
- Planting of other indigenous species with high conservation or cultural value on a smaller-scale and on suitable sites.
- Planting exotic forest, especially on sites where soil and water impacts of harvesting can be managed and where harvesting and transport costs are low enough to make commercial forestry profitable, with or without carbon revenues or East Coast Forestry Project (ECFP) funding.
- Planting wide-spaced trees on sites that can be managed for silvo-pastoralism (trees plus grazing) and where erosion severity is low enough that trees do need to be planted closely together.

Under the above strategy, restoration of natural forest could be achieved slowly by gradually reverting pastures to manuka and kanuka and looking to convert the more erosion-prone areas of existing exotic forest to natural forest. Exotic species such as radiata pine and fast-growing indigenous species such as manuka and kanuka can be used as ‗nurse' crops for the establishment of other indigenous species (Davis et al., 2009).

Davis et al. (2009) estimated a cost of $2,606 per ha (exclusive of fencing cost) to establish radiata pine, whereas estimated costs can range between $12,000-$36,000 per ha to establish indigenous forest by a mixture of planting and direct seeding. However, greater use of bare-root plants presents an opportunity for cost reduction if the difficulties with this approach identified by nurseries and establishers can be overcome. Natural regeneration is currently the lowest-cost means of establishing indigenous forest, although at an estimated $4,000 per ha it is still relatively expensive. A seed source is required for natural regeneration and competition from grass species is a major obstacle to establishment. Effective weed control and exclusion of animals are key factors and site selection (in terms of slope, aspect, and soil characteristics) is also an important consideration (Davis et al., 2009). Innovative ways to bring the cost of establishing indigenous forests down and to provide additional income from indigenous forestry require further exploration. The value of carbon sequestration associated with the restoration of natural forests could be accessed via the Permanent Forests Sinks Initiative (PFSI). The establishment of local nurseries by Ngāti Porou for the supply of indigenous plants may be an option to explore to help increase supply, reduce costs, and provide employment opportunities to the local people. Harmsworth et al. (2002) suggested that establishment of nursery operations could be linked to training and education opportunities around plant management, horticulture, matauranga of flora and fauna, and rongoa. Ngāti Porou established a small native plant nursery with Sustainable Management Fund (SMF) funding from MFE as part of a wider project to establish restoration initiatives in the Waiapu catchment (see Section 2.10.9). However, funding for the project was stopped after one year and the nursery is now in recess.

7.3.3 No further deterioration of the river & catchment

Urgent action is required to avoid further deterioration of the river and catchment from its current state, at least with respect to sediment yield from gullies. Modelling undertaken by Herzig et al. (2011) – discussed further below – suggests that the afforestation of at least all existing gullies by 2020 is required keep gully sediment yields near current levels (22 Mt/yr) by 2050 because new gullies and existing gullies too large to reforest will continue to generate sediment. If no gullies are planted after 2008, the sediment from gullies is predicted to increase from 22 Mt/yr to 45 Mt/yr by 2050 (Herzig et al., 2011).

7.4 Achieving a desired state

Throughout this research, Ngāti Porou have emphasised the need for holistic approaches to solving the problems facing the catchment. However, it may be assumed that the larger the area of erodible land that is afforested, and the sooner it is afforested, the more likely it is that the erosion will be brought under some degree of control. As the effects of the erosion problem are reduced, it would be reasonable to expect to see many of the aspirations measured under the indicators to be achieved, especially if erosion control is part of a wider strategy to improve the health and wellbeing of the catchment and its people.

From a cultural perspective, it will be essential that models of afforestation and forestry adopted to address the erosion problem include integrated management using matauranga Maori frameworks. Models for integrated management using matauranga Maori will need to come from Ngāti Porou and their implementation lead by Ngāti Porou rather than by external agencies. Resourcing to create a co-management and co-governance framework for the management of the river will be essential to ensuring that cultural models are implemented and integrated with existing systems. Similar processes that have ensured the ownership of the beds of lakes in Te Arawa and Ngāti Tuwharetoa have been returned to the tangata whenua provide examples of successful regimes that could be utilised in the case of the Waiapu. In addition the Waikato River Iwi Settlements and consequent legislation providing structure for co-management and co-governance of the Waikato River can provide learnings for a negotiated outcome for Ngāti Porou.

The relationship between the Waiapu and Ngāti Porou is dependent on a range of factors. Retaining the unique culture of Ngāti Porou will be foremost in the journey to re-connect with the river. Wananga on the river, reviving traditional methods of food gathering, the survival of Te Reo, celebrating oral history and waiata will all be part of better understanding the river. However, the key to rebuilding the relationship with, and subsequently the health of, the river will come from returning to the banks of the river — living on the river and understanding its nature and characteristics through the eyes of the people who have been on it the longest. This will be fundamental to the on-going sustainability of the river itself, the economy to bring people back, and the connection between river, whakapapa, and people.

With respect to the restoration of economic independence, landowners may need to consider amalgamation to reduce the impacts of land fragmentation and this will provide some economic scale with respect to production. Collective partnerships, like co-operatives may need to be fully examined and implemented on more of the smaller uneconomic blocks. Understanding wider land use options and land potential will be essential, and the involvement in research and development will need to be a collective role for the whole of the rohe.

7.4.1 Possible options for addressing the erosion problem

Possible options for addressing the erosion problem in the Waiapu catchment are provided here as starting-points for further consideration and development of solutions with Ngāti Porou and the local communities. However, in the broadest terms, a solution to the erosion problem will require the appropriate revegetation of eroding and erosion-prone land in order to limit sediment input to the stream and river networks within the catchment. The identification of site-specific solutions is beyond the scope of the present study. This detail will need to be worked out at a property level, using maps at scales of 1:5,000 to 1:15,000.

Recent modelling of gully-derived sediment yield from the catchment between 2008 and 2050 under different afforestation scenarios – with canopy closure models based on the growth rate of *P. radiata* at a density of 1250 stems ha^{-1} – was undertaken by Herzig et al. (2011). The results of the study provide some useful geophysical context and guidance with respect to the potential effectiveness of some possible options for addressing the erosion problem. However, it is important to note that the modelling deals only with gully-derived sediment yields (sediment yields associated with other erosion processes in the catchment have not been quantified or modelled) and that exotic afforestation was the only treatment approach investigated. The modelling shows that the most effective afforestation scenarios (in order of decreasing effectiveness) in terms of reducing sediment yield from gullies are to: (1) afforest all gullies (up to 20 ha in size) by 2020, (2) afforest gullies 5-15 ha in size, and (3) afforest all ECFP target land by 2020 (Herzig et al., 2011). The effect of planting lesser amounts of gullies and gully-prone land has not been modelled. An assumption included in the modelling was that new gullies continue to initiate at a rate similar to the historical rate of initiation. Projected annual gully-derived sediment yields at 2050 for key afforestation scenarios are given in Table 7.2.

Table 7.2. Comparison of gully-derived sediment yields for various afforestation scenarios.

Afforestation Scenario	Gully sediment yield at 2050 (Mt/yr)
No new gullies planted after 2008	45[†]
All Land Overlay 3A (LO3A) land planted by 2030	41[†]
All ECFP Target land planted by 2020	30.6[‡]
All existing gullies planted by 2020, but new gullies not planted	20[§]
All existing gullies planted by 2020, and new gullies planted	11[†]

[†] Herzig et al. (2011).

[‡] A. Herzig, pers. comm.

[§] Marden et al. (2011).

Afforestation leading to rapid canopy closure is generally expected to be the most effective approach to treating areas of eroding and erosion-prone land within the Waiapu catchment. Therefore, the possible options considered below are discussed in terms of afforestation as the default approach to the treatment of these areas. It is recognised that, for various reasons, other approaches to treatment may be preferred by landowners in some cases and that a suitable mix of afforestation, reversion, and wide-spaced tree planting may offer acceptable site-specific solutions. However, it must be noted that gully-derived sediment yields would be expected to be greater than those described above if approaches to treatment that involve longer periods of time to achieve canopy closure (e.g. natural reversion) or that will not involve canopy closure at all (e.g. wide-spaced tree planting) are used instead of afforestation. The implications of land use change and potential issues and opportunities around various approaches to the revegetation of eroding and erosion-prone land are considered below (Section 7.5).

The possible options outlined below are not in any particular order of priority.

7.4.1.1 Option One: Afforest all gullies & their associated catchments

The total area of gullies within the Waiapu catchment as at 2008 was 3,073 ha (see Section 4.7.2, Table 4.12). However, the treatment of these gullies and any newly initiating gullies will require the revegetation of a larger area of land surrounding the existing gullies and in locations where new gullies may form. The areas of gullies and their associated catchments within the Waiapu were determined by Landcare Research, and are presented in Table 7.3. Areas for all gullies as well as for all gullies excluding the largest gullies (> 20 ha in size) are presented. The modelling undertaken by Herzig et al. (2011) excluded gullies larger than 20 ha because they do not expect these very large gullies to be fully stabilised by treatment. Therefore, the focus of Option One is on areas excluding gullies larger than 20 ha although figures for all gullies are also given. All gullies and their associated catchments (excluding gullies > 20 ha) occupy about 23,000 ha within the Waiapu catchment. Of this area, 14,300 ha of land remain under grassland (based on the 2008 LUCAS land use map) and are potentially in need of treatment. It should be noted that the treatment of the entire area of a surrounding catchment may not necessarily be required in all cases. The area of each catchment to be treated would require assessment on a catchment by catchment basis. Note that this area (14,300 ha) excludes land under grassland with woody biomass.

Table 7.3. Areas of gullies and their associated catchments within the Waiapu catchment (data supplied by Landcare Research).

Area specification	Land area (ha)	
	All gullies excluding gullies > 20 ha in size	All gullies included
Area within the Waiapu catchment	22,940	35,061
Area currently under grassland†	14,300	21,659
Area not included within the ECFP target area	12,419	16,256
Area currently under grassland† and not included within the ECFP target area	8,328	10,824

† Does not include grassland with woody biomass

Assuming the afforestation of the entire area of gullies and their associated catchments (excluding gullies > 20 ha) under grassland is undertaken and funded through a mechanism such as the Afforestation Grants Scheme (AGS) for example, a cost of $2,400 per ha would be involved (MAF, 2011) and the approximate cost is estimated at $34 Million. However, if gullies larger than 20 ha were included in the area to be treated, the approximate cost of afforestation of 21,659 ha under the Afforestation Grants Scheme would be estimated at $52 Million (based on a cost of $2,400 per ha for the AGS as quoted in MAF, 2011).

If all existing gullies and their associated catchments and all new gullies that initiate are afforested by 2020 then the sediment yield will be 11 Mt/yr by 2050 (Herzig et al., 2011) (see Table 7.2). However, if all existing gullies in the catchment are afforested by 2020, but new gullies that initiate are not afforested, the sediment yield will be ~20 Mt/yr by 2050 (Marden et al., 2011). Therefore, of the modelled scenarios, only the afforestation of all gullies and their associated catchments will reduce gully sediment yield. This is because of the growth of unplanted gullies, the initiation of new gullies, and the continued growth of gullies too large to stabilise (> 20 ha).

The afforestation of all gullies and their associated catchments (i.e. planting the surrounding catchment area of gullies as is required for ECFP target land under the ECFP) is likely to be the most effective approach in terms of reducing sediment yield from gullies. This has traditionally been achieved by planting fast growing (canopy closure at ~8 years) exotic trees (mainly *P. radiata*). This approach is expected to produce the quickest results with respect to this option. However, the scenario of complete afforestation of all gullies and their associated catchments will, under present circumstances, be a challenge given the many social, economic, and cultural factors that influence the decision to afforest.

7.4.1.2 Option Two: Afforest all ECFP target land

Data supplied by MAF indicate that there are about 13,526 ha of ECFP target land yet to be treated (i.e. currently under grassland). Gully modelling suggests that even if all ECFP target land is afforested by 2020, the sediment yield from gullies will still increase from 22 Mt/yr (2008 figure) to 30.6 Mt/yr by 2050 (A. Herzig, pers. comm.) (see Table 7.2). The figure of 22 Mt/yr representing the ‗current' (as at 2008) sediment yield is taken from Herzig et al. (2011) and differs slightly from the figure of 23.97 Mt/yr provided to this study by Landcare Research which has been used in the Chapter 4 of this report on the description of past and present geophysical states of the catchment.

The approximate cost of treating the 13,526 ha of un-forested ECFP target land, if funded through ECFP is estimated in Section 6.6.3.6 at $24 Million (see Section 6.6.3.6 for approach used to estimate this cost). However, this assumes that no non-target land is afforested in association with the afforestation of the target land. If there is non-target land included, the total cost will be greater than estimated here, and will depend on the area of non-target land included in the land afforested. The area of non-target land that may require treatment in association with the target land is unknown. It is thought that about 30% of the land area afforested to date under the ECFP was non-target land (MAF, 2011).

Afforestation of 13,526 ha by 2020, when the ECFP is due to expire, may be achievable if the planting rate under the scheme in 2011 can be sustained. Planting rates under the ECFP have averaged 1,000 ha in the last three years, and not all of which would have been target land. However, 1,795 ha were planted in 2011 in response to the introduction GDC's LO3A rule and afforestation driven by carbon investors (R. Hambling, pers. comm.). Approved planting planned for the next three years includes about 1,200 ha of target land. However, these are interim figures only and are subject to further application rounds (R. Hambling, pers. comm.). To plant about 13,500 ha of target land in the next eight years will require the planting rate in 2011 to at least be sustained, if not increased. This may be a challenge given that most of the additional planting will need to be undertaken on a voluntary basis (under the current policy framework).

LO3A is a land use rule (contained within the Gisborne District's Combined Regional Land and District Plan) designed to support the ECFP by requiring the establishment and maintenance of an effective tree-cover on and around the worst of the eroding land by 2021 (GDC, 2003). However, the modelling of Herzig et al. (2011) showed that if LO3A land alone is planted by 2030, total gully-derived sediment yield will increase to about 41 Mt/yr by 2050 (see Table 7.2). Although, the modelling did not account for the expectation that wider areas of land surrounding the defined LO3A area may also be afforested to achieve an ‗effective tree cover' but as this area does not appear to be defined or documented it is not possible to include it in any analysis or evaluation.

The area of LO3A land is much smaller than the area of ECFP target land and, at a minimum (excluding any adjacent land that may be planted), only 7,770 ha of pasture land within the LO3A area is identified as requiring treatment within the catchment. This is expected to be achievable by 2021, and landowners will be required to achieve this target anyway. However, planting the LO3A area will leave a large area of land with very severe or extreme potential erosion untreated and at risk of erosion in high-magnitude rainfall events such as Cyclone Bola.

The estimated cost of reforesting all LO3A land under pasture (7,770 ha) is $16 Million based on the upper range in the ECFP grant rate for afforestation of $2,039 per ha based on figures supplied by MAF (R. Hambling, pers. comm.). As with ECFP target land, it is likely that a mix of afforestation, reversion, and wide-spaced tree planting would be undertaken across this area. The cost of reversion (based on the grant rate for the ECFP scheme) is $1,512 per ha, whereas the cost for wide-spaced tree planting is estimated to be 70% of $1,500 per ha for poplars (at 100 stems per ha) (Parminter et al., 2001) which equates to $1,050 per ha if funded under the ECFP.

7.4.1.3 Option Three: Afforest all ECFP target land plus all gullies & their associated catchments

This option represents the combination of Options One and Two where all ECFP target land is treated and, in addition, all gullies and their associated catchments (excluding gullies > 20 ha) occurring outside the ECFP target land are also treated. Based on the work of Herzig et al. (2011), the afforestation of all gullies (up to 20 ha in size) is required to reduce annual sediment yields. Gully-derived sediment constitutes about 49% of the sediment yield of the Waiapu River (Marden et al., 2008). Under this option, some reduction in the sediment yield attributable to other erosion processes (landslides and earthflows) may be expected in addition to the reduction in gully-derived sediment yield (in response to the afforestation of all gullies) as modelled by Herzig et al. (2011). However, these yields have not been quantified and are expected to be relatively small (M. Marden, pers. comm.).

All gullies and their associated catchments (excluding gullies > 20 ha) that are not included within the ECFP target area occupy an area of 12,419 ha (see Table 7.3). Of this area, 8,328 ha of land remain under grassland and are potentially in need of treatment (based on the 2008 LUCAS land use map). When combined with the area of ECFP target land requiring treatment

(13,526 ha), the total area of land to be treated under this option would be 21,854 ha. However, if gullies larger than 20 ha were also treated, the total area to be treated would be 24,350 ha. It should be noted that the treatment of the entire area of a surrounding catchment may not necessarily be required in all cases. The area of each catchment to be treated would require assessment on a catchment by catchment basis.

The approximate cost of afforesting the area of gullies and their associated catchments that do not occur within the ECFP target area (again using the example of the AGS with a cost of $2,400 per ha as quoted by MAF, 2011) is estimated at $20 Million (or $26 Million if gullies larger than 20 ha are also treated). When added to the approximate cost of afforesting the remaining ECFP target land, the total approximate cost for this option is estimated to be $44 Million (or $50 Million if gullies larger than 20 ha are also treated). Even based on the rate of afforestation under the ECFP for 2011 (1,795 ha), planting of the total area of land identified under this option by 2020 would appear to be a significant challenge without a change in approach.

7.4.1.4 Option Four: Afforest all Potential Erosion Severity 4 & 5 land

It was estimated in this study that approximately 19,400 ha of land within the catchment has a potential erosion severity (PES) of very severe (4) or extreme (5) and was under grassland as at 2008 (see Section 5.3.1). If the area of land under grassland with woody biomass is also included, the total to be treated would be about 21,500 ha. It is likely that land with PES 4 or 5 will require an intact forest (closed canopy) to achieve a significant reduction in erosion on this land. The effect of afforesting or otherwise treating all PES 4 or 5 land on sediment yields within the Waiapu catchment has not been investigated and is currently unquantified. Future work will be required to establish the effectiveness of this option in terms of sediment yield or other indicators. However, the effective treatment of this land will impact on sediment yields from both gullies and other sources (e.g. landslides and earthflows). The approximate cost of afforesting the 19,400 ha of highly erodible land under this option is estimated at $47 Million, if afforestation is funded using a mechanism such as the AGS (at $2,400 per ha). It is likely to be a significant challenge to achieve full treatment of 19,400 ha of land within the next decade.

7.4.1.5 Option Five: Afforest all Potential Erosion Severity 4 & 5 land plus all gullies & their associated catchments

The net area of land within the Waiapu catchment that encompasses all grassland with a PES of very severe (4) or extreme (5) and all gullies and their associated catchments under grassland (excluding gullies > 20 ha which are too large to stabilise) as at 2008 was estimated to be up to a maximum of about 28,000 ha. This estimate was derived by adding the area of PES 4 or 5 land within the catchment that was under grassland (19,400 ha) to the area of gullies and their associated catchments under grassland not included within the ECFP target area (8,328 ha). All ECFP target land has a PES of 4 or 5. However, geospatial analysis (involving the intersection of NZLRI and LUCAS 2008 data) has indicated that there were approximately 4,000 ha of Land Use Capability (LUC) class 7e1 and 7e6 land under grassland (as at 2008) in the catchment with a PES of 4 or 5 that is not included within the ECFP target area. Therefore, there may be up to a maximum of about 4,000 ha of overlap between the area of PES 4 or 5 land and the area of gullies and their associated catchments under grassland not included within the ECFP target area. This means that the net area could be as low as about 24,000 ha, but it is unlikely to be this low because it is expected that not all of the approximately 4,000 ha of the PES 4 or 5 land in question will overlap with the area of gullies and their associated catchments under grassland. It should be noted that the treatment of the entire area of a surrounding catchment may not necessarily be required in all cases. The area of each catchment to be treated would require assessment on a catchment by catchment basis.

As with Option Four, the effect of afforesting or otherwise treating the net area of land encompassing all grassland with a PES of 4 or 5 and all gullies and their associated catchments under grassland (as at 2008) within the Waiapu catchment has not been investigated and is currently unquantified. Future work (including long-term monitoring) will be required to establish the effectiveness of this option in terms of sediment yield or other indicators.

The approximate cost of afforesting the 28,000 ha (maximum estimate) of eroding and erosion-prone land under this option is estimated at $67 Million, if afforestation is funded using a mechanism such as the AGS (at $2,400 per ha). It is likely to be a significant challenge to achieve full treatment of 28,000 ha of land within the next decade.

7.4.2 Summary of possible options

The possible options for addressing the erosion problem in the Waiapu catchment outlined above are summarised in Table 7.4 in terms of the area of land involved and estimated approximate cost.

Table 7.4. Land area and estimated cost associated with the possible options for addressing the erosion problem.

Possible option	Land area involved (ha)	Estimated cost ($ Million)
Option One: Afforest[§] all gullies & their associated catchments	14,300*	$ 34
Option Two: Afforest all ECFP target land	13,526[†]	$ 24
Option Three: Afforest all ECFP target land plus all gullies & their associated catchments	21,854*	$ 44
Option Four: Afforest all Potential Erosion Severity 4 & 5 land	19,400	$ 47
Option Five: Afforest all Potential Erosion Severity 4 & 5 land plus all gullies & their associated catchments	28,000*[‡]	$67

* Area excludes area of gullies > 20 ha in size.

[†] Figure provided by MAF and assumes no non-target land is treated in association with the target land (the area of non-target land that may require treatment in association with the target land is unknown).

[‡] Estimated maximum area needing treatment.

[§] Options discussed in terms of afforestation as the default approach to treatment.

7.5 Land use change implications – issues & opportunities around approaches to the revegetation of eroding & erosion-prone land

The possible options to control erosion identified above in Section 7.4.1 suggest that up to about 28,000 ha of the land remaining under grassland in the Waiapu catchment will need to be treated (with afforestation as a default approach) in order to more toward achieving some aspects of a desired state. In this section we briefly describe the implications of the land use changes associated with these options and consider the issues and opportunities around approaches to the revegetation of eroding and erosion-prone land. The socio-economic and cultural context around the land use change is also briefly considered.

7.5.1 Socio-economic & cultural context & implications

The general socio-economic and cultural context around the erosion problem in the Waiapu catchment is provided by the assessment of the scope (size and scale) of the problem and the description of the states of the catchment in terms of its social, economic, and cultural impacts (see Chapter 6). The possible options for addressing the erosion problem outlined above should be viewed in relation to this general socio-economic and cultural context.

Drivers for and barriers to landowner engagement in developing and adopting interventions to address the erosion problem in the catchment might be expected to be influenced by prevailing socio-economic conditions as well as by cultural aspirations. Giera et al. (2007) discussed the findings of New Zealand-based case studies that involved the examination of landowner awareness, attitudes, and responses to erosion and the factors that affect these. One of the case studies was based around the ECFP. They found that although there was a high level of awareness of erosion issues on the East Coast and recognition of the benefits of erosion control, commercial forestry was viewed by farmers as a threat to the social and economic health of their communities (Giera et al., 2007). Across all case studies described, survey respondents identified that the main factors driving farmers to respond to erosion problems were: (1) economic costs and benefits, (2) concern regarding environmental impacts, (3) the visibility of damage, and (4) being able to see results (Giera et al., 2007). Giera et al. (2007) went on to identify key factors affecting uptake of erosion control measures based on all of the case studies they undertook. These included:

- Understanding of economic and environmental impacts of erosion and benefits of mitigation. Provision of clear scientific justification and context is important. Barriers to uptake of erosion control practices were identified as (1) scepticism as to the effectiveness of mitigation measures, (2) a lack of information, and (3) perceived risk.
- A need for both financial and technical support (e.g. Council supported farm plan development and farmer discussion groups).
- Strong local leadership and skilled facilitation to bring key stakeholders together and to ‗show the way' through demonstration of mitigation measures.
- Cultural awareness and recognition of the complexities associated with multiple land ownership.
- Financial costs and pressures to maintain productivity to service debt.
- Restrictive regulation and bureaucracy. The involvement of Councils in terms of monitoring and enforcement was thought by some to aggravate and isolate farmers. Findings of the ECFP case study highlighted the need for farmers to feel that they are being treated fairly and that they have options available to them in terms of erosion control treatments (Giera et al., 2007).

7.5.1.1 Uptake of the ECFP

It has been recognised that uptake of ECFP grants has been slow and, as a consequence, the scheme has struggled to achieve significant areas of afforestation, reversion, or wide-spaced tree planting (MAF, 2011b). Giera et al. (2007) pointed out that although the ECFP has been successful at encouraging forestry companies to afforest target land, uptake of the scheme by pastoral farmers has not been as good. A high rate of approved applications falling-through before establishment has occurred (i.e. ‗drop-out rate'), has been noted. The high drop-out rate and general lack of uptake has been attributed to several factors including:

- The need for bridging finance. The grant payments are retrospective and so, unless the landowners have sufficient finance available up-front, short-term bridging finance or investment of a joint-venture partner must be found. As noted elsewhere in this report, securing bridging finance can be an issue for Ngāti Porou.
- Difficulty in achieving landowner sign-off where land is under multiple- or absentee-ownership (e.g. Māori land).
- Lack of real interest in following through with the land use change.
- Inability to establish approved plantings within the year of approval due to various delays.
- The introduction of 50-year covenants to prevent the deforestation of forests established under the ECFP. In addition to generally adding complexity, covenants create a particular barrier in the case of Māori land under multiple-ownership because approval must be sought from the Māori Land Court for the alienation of the land. Approval may not be granted for the 50-year period. The Afforestation Schemes Review Panel recommended replacing the covenants with contracts like those used under the Afforestation Grants Scheme.
- Restrictive forestry regimes. It was suggested that more flexibility around prescribed forestry regimes in terms of stocking rates (e.g. allowing lower initial stocking followed by only one thinning may reduce costs involved substantially) and consideration of alternative species.
- Policy around ETS (Forestry). The ECFP grant may be reduced if the grantee (post-2007) chooses to join the ETS forestry. While it is not though that this policy has had a substantial effect on uptake so far, it may have a detrimental effect on future uptake given that increased interest in afforestation through carbon farming opportunities is expected (MAF, 2011b).

The authors of the Afforestation Schemes Review (MAF, 2011b) suggest that the slow uptake of ECFP grants may change if it is operated in conjunction with the Permanent Forest Sinks

Initiative (PFSI) or Emissions Trading Scheme (ETS) (Forestry), in relation to opportunities around carbon farming.

In a case study of the ECFP, Giera et al. (2007) canvassed the views of a range of stakeholders including farmers, GDC staff, farm and forestry consultants, those involved in past reviews of the project, and the manager of the scheme. Some of the main findings reported may provide some explanation for the slow uptake of the scheme by pastoral farmers:

- Some farmers were concerned that expansion of commercial forestry might adversely affect local communities in terms of social and economic wellbeing.
- The negative perceptions of forestry, as expressed by many of the stakeholders, may have been formed by the commercial failure of two large forestry companies in the late 1990's and the economic hardship felt by communities as a result.
- The perception was expressed that there had been political interference in the design and scale of the ECFP and that it had been developed in Wellington without sufficient local consultation.
- Funded treatment options were too prescriptive and not sufficiently flexible to account for local variations in soils and landforms.
- Farmers with smaller properties may have less flexibility to change land use without negatively affecting the economic viability of their businesses.
- Improvements in economic returns from pastoral farming, particularly relative to returns from forestry, may limit uptake of the scheme which relies on a financial incentive for land use change (Giera et al. 2007).

7.5.1.2 Tenure of land to be established in trees

Table 7.5 provides a breakdown of land ownership for the 19,400 ha of land with PES of 4 or 5, currently in low-producing grassland.

Table 7.5. Areas under low-producing grassland with very severe (4) or extreme (5) Potential Erosion Severity (PES) by current land tenure (as at 2011). All areas are in hectares.

Tenure	PES 4	PES 5
Crown Land	348	0
DoC Land	48	107
Māori Title	5493	348
General Title	12,569	74
Total	**18,458**	**529**

Crown ownership comprises mainly Crown Forestry Licences (Crown land) and conservation lands (DoC land). While Crown land and the conservation estate have a higher proportion of highly erodible land than private and Māori land, there is very little highly erodible land (PES 4 or 5) in Crown ownership that remains in grassland. It is clear that the burden of establishing trees on the remaining highly erodible land in grassland falls squarely on private and Māori landowners; most is in various forms of private ownership, with 22% in Māori title. As noted in Section 7.4.1.2, apart from the afforestation of LO3A areas mandated by the GDC's Combined Regional Land and District Plan, the establishment of trees for erosion control on private land is voluntary. Reasons why landowners may not choose to establish trees, even on highly erodible land, are discussed in Sections 6 and 7.4.1.2, and are considered below.

7.5.1.3 Economic implications

Economic effects of soil erosion in the Waiapu catchment include soil degradation and loss of life-sustaining capacity along with damage to infrastructure, both on and off-farm. These effects are discussed more fully in Chapter 6. While local landowners and the wider community are aware of these effects, there is a greater or lesser acceptance of these as a part of farming on the East Coast, and this may mean that landowners are not sufficiently motivated to plant trees on highly erodible land.

As reported by Giera et al. (2007), landowners may fail to establish trees on highly erodible land for a number of reasons, including the costs involved and a lack of time to plan and carry out the tree planting. However, none of these barriers are insurmountable, provided the landowner believes that erosion is a major problem and combating it is a very high priority. Although cost and time are barriers, these could at least partially be overcome by funding from the ECFP or other afforestation schemes. However, the ECFP does not compensate for lost grazing revenue when pasture is converted to trees. Furthermore, New Zealand farms are subject to economies of scale, and if a farm must reduce stock numbers because of lost grazing then this may mean that it falls below the minimum size for economic viability. In contrast, retiring marginal grazing areas by establishing trees can allow a farmer to concentrate inputs on the remaining portion of the farm, where returns on inputs are superior. This may actually result in an increase in stock carrying capacity and increased farm performance, although evidence for this is mostly anecdotal and has received very little formal study in New Zealand (one example is Harris, 1982).

7.5.1.4 Effects on communities

Sections 3 and 6 describe the effects on East Coast rural communities of rapid afforestation with radiata pine since 1960. Some of these effects are positive, but any rapid change to people's livelihoods and ownership of property has a disruptive effect. Specific effects include:

- Depopulation of rural areas and small towns, with subsequent loss of services and sense of community.
- Transfer of ownership from within the community, either to the State or to forestry companies that are typically owned or financed from overseas.
- Government intervention in the form of rules or incentive schemes, both of which may reduce autonomy of local landowners and the wider community.

Attribution of these effects entirely to forestry needs to be qualified — as noted in Chapter 6, the larger the geographical unit of analysis, and the longer the timeframe, the greater chance there is of multiple or cumulative sources of change leading to human impacts, and the more difficult it becomes to attribute particular amounts of impact/cost to particular causes." Rural depopulation and decline of rural communities has occurred for many decades throughout New Zealand and has many causes. Forestry is not for the sole cause of this.

These effects on communities could be softened by slower progress toward afforestation, allowing communities to find ways to adjust to land use change and to participate in the process of afforestation. Unfortunately, while a slower rate of tree establishment may allow land use to evolve in a way that does not result in the dislocation to rural communities; it will also slow progress toward achieving the erosion-related aspects of a desired state for the Waiapu.

An alternative viewpoint is that the required tree establishment must occur on land largely owned by private individuals at present. With assistance from the ECFP and other grant schemes, it may be possible for landowners to achieve treatment targets while retaining ownership of the land and the livelihoods they derive from it. This approach may limit any adverse effects of land use change on the farming community. However, it would require the farming community to act with cohesion and to be prepared to adopt land uses (e.g. silvo-pastoralism, farm forestry, or indigenous forestry) and, perhaps also, business structures (e.g. forestry co-operatives and joint ventures) that differ from current land use and farm business practices.

Of the barriers to tree establishment discussed in this section, it is the social issues that, perhaps, are the most important. Only 7,770 ha of further tree establishment are mandated under the Gisborne Combined Regional Land and District Plan, within the LO3A area. The balance of land that requires tree establishment in order to move toward achieving some aspects of a desired state for the catchment must be planted on a voluntary basis, under the current policy framework. If the barriers to tree establishment on farms described by Giera et al. (2007) and the issues specific to forestry on Māori-owned land are not overcome, there is a risk that a desired state may not be achieved.

7.5.1.5 Cultural aspirations

Reduced erosion and sediment yields through intervention (i.e. the treatment of eroding and erodible land) would appear to be consistent with the aspirations Ngāti Porou have expressed for the catchment and would go some way toward achieving some aspects of a desired state. Given that the protection and restoration of natural forests is a key element of a desired state for the catchment as expressed by Ngāti Porou, the exploration and adoption of approaches to treating the erosion problem that, where appropriate, involve the use of natural reversion and indigenous species will be required. Approaches that provide employment for local people as well as opportunities for innovation, entrepreneurship, and regional economic development will also be needed to help address Ngāti Porou‘s aspirations around the restoration of economic independence. There appear to be a range of views among Ngāti Porou with respect to the use of exotic afforestation (and commercial forestry) in erosion control in the Waiapu catchment with some expressing concern (e.g. see Section 6.5.2.5) and others in support (as evidenced by the 9,911 ha of Ngāti Porou land committed to NPWFL).

7.5.2 Implications, issues, & opportunities around treatment approaches

The majority of afforestation carried out since 1969, with the aim of reducing erosion, has been undertaken using radiata pine and other fast-growing commercial tree species. On an area basis, wide-spaced tree planting with poplars and willows has been minor. Reversion of pasture to kanuka/manuka and other scrub or indigenous forest has been counteracted by clearance of scrub vegetation for afforestation or conversion to pasture. The total area of scrub and natural forest in the catchment was 62,845 ha in 1969, 61,290 ha in 1990, and 60,107 ha in 2008 (see Chapter 4). This is not to say that the further treatment of land to control the erosion problem in the catchment needs to be predominantly exotic afforestation with radiata pine. A mix of treatment approaches is possible and could involve:

- Natural regeneration of indigenous species such as manuka and kanuka, and planting of other indigenous species with high conservation or cultural values on a smaller-scale and on suitable sites.
- Planting exotic forest, especially on sites where soil and water impacts of harvesting can be managed and harvesting and transport costs do not limit profitability.

- Wide-spaced tree planting (poles and wands) on sites that can be managed for silvo-pastoralism (trees plus grazing).

It is important to note that effective management of pests (both weeds and animal pests) is, in most cases, required for the successful establishment and maintenance of woody biomass vegetation (including afforestation, reversion, and wide-spaced tree planting) for erosion control or other purposes (e.g. Davis et al., 2009; Burns et al., 2011). The main approach to controlling weeds in hill country is the application of herbicide (Davis et al., 2009). The exclusion of feral and grazing animal pests from areas of revegetation may be achieved through the use of appropriate fencing. The cost of fencing for establishment of indigenous species and radiata pine was cited as $4000 per ha by Davis et al. (2009). Operations to control animal pests (which include possums, goats, deer, pigs, and feral cattle) should be maintained to ensure that animal pest numbers are kept to a minimum. Estimates of costs of weed and pest control activities are given in Davis et al. (2009).

7.5.2.1 Afforestation

Afforestation with commercial plantations may have both positive and negative implications with respect to a desired state for the catchment. From a soil conservation viewpoint, once planted they are more effective than wide-spaced tree plantings and natural forest at rapidly establishing an effective canopy and root system to prevent erosion. However, this form of forestry may entail clear-fell harvesting on a 10-30-year cycle. This results in roads, landings and other earthworks, which in conjunction with the loss of a complete forest canopy for up to eight years (until the replanted plantation forest crop establishes and reoccupies the site) and the decomposition of root systems of harvested trees means a temporary increase in erosion susceptibility. Root systems of harvested P. radiata trees decompose and loose tensile strength over time, with zero root tensile strength after 3.3 years for roots less than 3 cm diameter (O'Loughlin & Watson, 1979). From the viewpoint of the community, commercial plantation forestry has drawbacks (see Sections 3 and 6). Although offering employment, the work is physically demanding and employment is not dependable, varying with the market cycles and changes in forest ownership that are experienced by the plantation forestry industry. Economies of scale operate in plantation forestry, favouring large companies or investors, rather than local landowners. However, it is likely that plantation forestry with commercial species will be the preferred land use on sites where the following apply:

- Erosion is too severe to justify planting with poplar wands and poles and there is a need to rapidly establish an intact forest canopy on unstable land.
- Landowners desire a land use with assured revenue of the same order as the existing pastoral grazing.

Although there are range of species that can be used for wood production and carbon sequestration, fast-growing eucalypts (especially for carbon sequestration) and radiata pine are the most likely species to be used.

If commercial plantation forestry is the preferred land use, the sale of farmland to a forestry company is not the only option. Ngāti Porou Whanui Forests Ltd (NPWFL) have shown that viable commercial forests can be established on Māori-owned land, using joint venture agreements between the landowners and forestry companies under the Forestry Right Registration Act, 1983. It is possible to retain autonomy and local ownership, even when converting farmland to commercial forestry plantations. However, as mentioned earlier, joint ventures and other co-operative relationships require a cohesive approach, both within the community and between the community and the forest investors. It takes commitment to maintain that cohesion over a 30-year forestry rotation, especially as those entering into the agreement are unlikely to be the partners to the agreement by the end of the rotation. By that time, a new generation has succeeded to ownership of the land, and the forest investment may have passed through several changes in ownership.

A barrier to production forestry with pines and hardwoods in terms of the economic drivers for establishment is that they become unprofitable where difficult logging terrain and long cartage distances mean that harvesting and cartage costs consume the value of the log, leaving very little profit for the forest owner. The effect of harvesting and cartage cost on returns to the grower are shown in Figure 7.2. Barriers in terms of the profitability of harvesting the more isolated East Coast planted forests may be overcome by carbon credit revenue and by the financial contribution of the ECFP to establishment cost. However, any potential risks associated with carbon trading should be evaluated carefully. Currently, 9,911 ha of Ngāti Porou land have been committed to NPWFL. Opportunities around carbon forestry are attracting even more Ngāti Porou into forestry with carbon deals occurring across the East Coast at present.

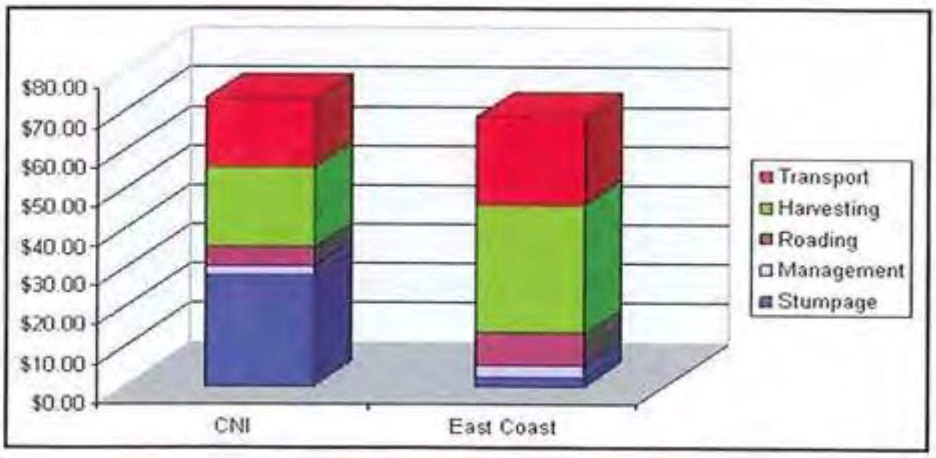

Figure 7.2. Comparison of cost structure for planted forests in the East Coast vs. Central North Island. The y-axis shows the proportion of total log price, delivered to mill, that must be allocated to harvesting and transport before a residual stumpage is paid to the forest owner (reproduced from Raymond, 2010).

Based on discussion and anecdote, the two issues for Ngāti Porou in relation to the establishment of forestry ventures arise from the limitations of multiple land ownership, which:

1. Requires full agreement among shareholders before land can be committed to long-term ventures like forestry. The lack of full agreement has stymied several large-scale plantation forestry projects on Ngāti Porou land in the last decade (a notable exception being NPWFL).
2. Makes it difficult to participate in the ECFP, because the ECFP requires landowners to establish forests from their own funds before retrospectively claiming establishment costs. This entails a minimum of two and a half months delay in payment of ECFP grants after establishment is complete. Māori landowners find it difficult to generate bridging finance between the point where establishment costs are incurred, and payment of ECFP grant money.

On sites where conventional commercial plantation forestry is not sustainable in economic or environmental terms, alternative forestry systems to better suit the needs and aspirations of local communities and the steep, erodible hill country terrain could be investigated. Two possible alternatives could be:

1. Sustainable forest systems that produce high quality wood (niche products) and in which the management, harvesting, and processing is undertaken by local communities (i.e. ‗community forestry systems'). An examination of potentially suitable alternative (to *P. radiata*) species (including indigenous species), harvesting and transport systems, community processing options, and market opportunities would need to be undertaken. The examination of alternative forestry systems should take economic performance and effectiveness with respect to erosion control into account.

2. Commercial plantation forests on the East coast often develop an understory of indigenous forest species as the stands grow to maturity. With careful management, the plantation trees can act as a nurse crop, with an eventual succession to a natural forest. This may be a feasible option for plantation forests managed as permanent forest sinks for carbon (i.e. with no clear-felling). If the plantation species are not clear-felled, these relatively short-lived species will eventually decline and be replaced by the indigenous tree species growing in their understory. Carbon credits earned by the developing plantation could generate revenue, although once the stand has reached its maximum standing biomass, there would be no further opportunity for carbon revenue. This option is not incompatible with the alternative given above, in that partial (non-clearfell) harvesting of permanent forests is possible, so long as the standing forest biomass remains constant from year to year.

Planning for regional economic development should take regional wood availability forecasts into account (e.g. MAF, 2008). The forecast for the East Coast suggests a large (peaking at more than 100%) increase in wood supply (recoverable volume) will occur in about 12 years from present and will be followed by a steady decline in supply through to around 2035 (MAF, 2008). Planning for growth in, and maintenance of, future wood supply will be important for sustaining the associated economic opportunities for local communities and the region and the avoidance of large areas of even-aged production forests will help limit the area of land susceptible to accelerated erosion after harvest. Wood supply forecasts for the region could be updated and communicated to key stakeholders (particularly Ngāti Porou and the GDC) together with an analysis of implications and opportunities.

7.5.2.2 Natural reversion and indigenous forestry

Key issues and opportunities around the establishment of indigenous forests as an approach to erosion control were discussed above (see Section 7.3.2). Natural reversion (e.g. regeneration of manuka/kanuka stands) is considered to be as effective an approach to erosion control as exotic afforestation, except that the time taken for it to become effective will be greater (Bergin et al., 1995). The choice between exotic and indigenous species or natural reversion will likely be made using a mix of criteria, of which the time until effectiveness is achieved is only one. A pragmatic approach could, for example, be to target exotic afforestation on gullies and their associated catchments, and use other criteria (e.g. erosion type and cultural, social, economic, and ecological considerations) to target the establishment of indigenous forests or natural reversion elsewhere.

Research shows that mature manuka and kanuka stands, older than ≥15 years, are as effective for erosion control as radiata pine of 8 years or older (e.g. Bergin et al., 1995). However, establishment of kanuka/manuka is not cost-free. It requires good fencing to exclude stock, and a commitment to the control of fire and vertebrate pests such as possums. At more productive sites it may initially also need periodic light grazing to remove competing grasses which may otherwise smother the young tree seedlings (N. Ledgard, pers. comm.). Once the kanuka/manuka establishes an intact canopy (the time taken for this will vary with site and the density of existing seedlings) then no further grazing will be possible. Any revenue from this regenerated forest will depend on whether it is eligible for the ETS or other schemes where it can earn carbon credits, and the possibility of management for honey or pharmaceutical production.

If undisturbed, and if seed sources for indigenous tree species are available, then the kanuka/manuka will ultimately transform into tall natural forest, a process called ‘succession’. This may be considered a desirable final state, especially if the natural forest contains plant and animal species of high cultural or conservation value. However, the replacement of the kanuka/manuka forest by a so-called ‘climax’ forest of species like beech, totara, and matai will mean: (1) a loss of revenue from the kanuka/manuka products and (2) the forest will no longer be increasing its standing biomass, and there will be no further net sequestration of carbon by the forest. Unless other forms of income-generating uses can be developed, the forest may generate little further direct revenue. Note that this process will occur over a long period of time; a predicted succession for a South Island site estimated that kanuka would decline after 100 years, and maximum standing biomass would occur after 300 years (Hall, 2001). Note that the succession of kanuka/manuka to natural forest can be hastened by strategic planting of desired species. The plantings can act as a seed source for these species, so that they more rapidly establish under the kanuka/manuka canopy as it begins to decline.

A continuous cover forestry approach, as defined by Barton (2008), could be considered in relation to the establishment of indigenous forestry. This approach involves the management of the forest in-line with natural processes with the maintenance of a canopy and allowing for natural regeneration. Selective harvesting of individual trees or the felling of small coupes could be practiced within the resulting uneven-aged forest. In addition to maintaining the potential erosion-control function of the forest, cultural (including rongoa Māori), economic, and biodiversity objectives could also be met (Bergin & Steward, 2011). Small-scale economic opportunities around indigenous forestry or natural reversion may include manuka honey production, production of oils for use in medicines, timber production, and the supply of seeds and cuttings for use in the horticultural industry (Bergin & Steward, 2011).

7.5.2.3 Wide-spaced tree planting

Assuming that pastoral farming will continue to be a significant land use for Ngāti Porou and other landowners within the catchment, the planting of wide-spaced trees (principally poplars and willows) will continue to be required on a variety of erosion-prone land. These land types (LUC units) and erosion processes are well known, and have been identified at the regional scale by the NZLRI, and continue to be mapped at the farm-scale by GDC.

The advantage of wide-spaced tree planting (e.g. poplar wands and poles) is that it is more compatible with pasture and can be managed as part of an existing grazing operation on a pastoral farm. It is more likely that this form of treatment can be established without a change in ownership or land use on the property. However, planting with poles and wands is more expensive on a per tree basis than with radiata pine and the kinds of tree densities and size of planted area needed on severe erosion features (200-400 stems/ha, planted over entire sub-catchments) may be prohibitive in cost. Furthermore, large areas with high stockings may only be affordable if planted with the smaller wands, rather than the larger, more expensive poles. However, poles can be grazed by sheep within a year of establishment whereas wands may still need stock exclusion for several years in order to establish which means that there may be a temporary loss of grazed area involved with wand establishment.

O'Loughlin et al. (2008) concluded that willow and poplar pole planting were sufficient for erosion control if site factors that could potentially jeopardise successful establishment were taken into account, and if plantings were established at the recommended densities/spacing, and maintained appropriately. However, they caution that gullies deeper than 5 m, on bentonitic or crushed argillite lithologies, are unlikely to be successfully treated with pole planting unless accompanied by afforestation or reversion of the surrounding watershed. Afforestation, with either pine or indigenous reversion, is the most practical option for stabilising large active gullies.

7.6 Summary & conclusions

- A desired state for the Waiapu River and catchment, as expressed during the consultation with Ngāti Porou undertaken as part of this study, is presented and its key elements summarised.
- The achievability of controlling erosion in the context of a desired state is assessed in relation to (1) improved water quality and river condition, (2) protection and restoration of natural forests, and (3) no further deterioration of the river and catchment.
- In the absence of relevant New Zealand-based information, international examples suggest that restoration of river conditions following woody revegetation may take in the order of multiple decades to a century.
- Mechanisms (e.g. Nga Whenua Rahui) are available for the protection of exiting areas of natural forest. At least in the short-term, large scale artificial re-establishment of natural forests to control erosion is unlikely to be practicable due to issues of supply and cost of nursery-raised seedlings. However, a mixed treatment strategy involving natural regeneration and small-scale planting of key sites could be financially and practically possible.
- Urgent action is required to avoid further deterioration of the river and catchment from its current state, at least with respect to sediment yield from gullies. If no gullies are planted after 2008, the sediment from gullies is predicted (by Herzig et al., 2011) to increase from 22 Mt/yr to 45 Mt/yr by 2050.
- We make comment on possible options to control erosion (involving the revegetation of eroding and erosion-prone land) in order to move toward addressing aspects of a desired state for the catchment. The suggested options are starting-points for further consideration and development of solutions with Ngāti Porou and the local communities.
- From a cultural perspective, it will be essential that models of afforestation and forestry adopted to address the erosion problem include integrated management using matauranga Maori frameworks.
- Recent modelling of gully-derived sediment yield from the catchment between 2008 and 2050 under different afforestation scenarios was undertaken by Herzig et al. (2011). The results of the study provide some useful geophysical context and guidance with respect to the potential effectiveness of some possible options for addressing the erosion problem.
- Afforestation leading to rapid canopy closure is generally expected to be the most effective approach to treating areas of eroding and erosion-prone land within the Waiapu catchment. Therefore, the possible options are discussed in terms of afforestation as the default approach to the treatment of the areas involved although it is recognised that

a suitable mix of afforestation, reversion, and wide-spaced tree planting may offer acceptable site-specific solutions.

- The following possible options are suggested:
  - Option One: Afforest all gullies and their associated catchments.
  - Option Two: Afforest all ECFP target land.
  - Option Three: Afforest all ECFP target land plus all gullies and their associated catchments.
  - Option Four: Afforest all Potential Erosion Severity 4 and 5 land.
  - Option Five: Afforest all Potential Erosion Severity 4 and 5 land plus all gullies and their associated catchments.
- Comment on the land use change implications of, and potential issues and opportunities around, the various approaches to the revegetation of eroding and erosion-prone land is made.
- A mix of treatment approaches is possible and could involve:
  - Natural regeneration of indigenous species such as manuka and kanuka, and planting of other indigenous species with high conservation or cultural values on a smaller-scale and on suitable sites.
  - Planting exotic forest, especially on sites where soil and water impacts of harvesting can be managed and harvesting and transport costs do not limit profitability.
  - Wide-spaced tree planting (poles and wands) on sites that can be managed for silvo-pastoralism (trees plus grazing).
- Sediment yields would be expected to remain higher for longer periods of time if treatment options that take longer to achieve canopy closure (e.g. natural reversion), or that will not involve canopy closure at all (e.g. wide-spaced tree planting), are used instead of afforestation.
- The socio-economic and cultural context around the land use change is briefly considered. This included consideration of land tenure of highly erodible land under grassland, some economic implications, potential effects on communities, and cultural aspirations.
- It has been recognised that uptake of ECFP grants has been slow and, as a consequence, the scheme has struggled to achieve significant areas of afforestation, reversion, or wide-spaced tree planting. Possible reasons for the slow uptake of the scheme, as identified in the literature, include:
  - Financial and economic barriers (e.g. bridging finance and comparative returns from pastoral farming).
  - Complexity due to the multiple land ownership of Māori land.

  - Limitations of the scheme (e.g. must establish in year of approval, covenants, restrictive forestry regimes, and compatibility with the ETS).
  - Landowner perceptions of forestry and government (both central and local).
  - Availability of information, support, and leadership.
  - The absence of a co-management or co-governance model with Ngāti Porou.
- Reduced erosion and sediment yields through intervention (i.e. the treatment of eroding and erodible land) would appear to be consistent with the aspirations Ngāti Porou have expressed for the catchment. The exploration and adoption of approaches to treating the erosion problem that, where appropriate, involve the use of natural reversion and indigenous species will be required. Approaches that provide employment for local people as well as opportunities for innovation, entrepreneurship, and regional economic development will also be needed to help address Ngāti Porou's aspirations around the restoration of economic independence.

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8 Key conclusions

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The key conclusions of the Waiapu River catchment study are given below for the geophysical and land use aspects, and for the social, cultural, and economic aspects.

Geophysical & land use aspects

- Rates of natural erosion and sedimentation are high in the Waiapu catchment and deforestation during the late 19th and early 20th centuries has resulted in a significant and growing erosion problem. Larger rivers within the catchment are still aggrading and their channels are continuing to widen. Gully-derived sediment yields have increased between 1957 and 2008. Current annual sediment yields from the Waiapu River are very large in comparison to other rivers in New Zealand.
- Afforestation, reversion, and wide-spaced planted trees are all known to be effective in reducing erosion and about 54,000 ha of land in the Waiapu catchment has been afforested to date.
- It is estimated that the effective treatment of up to about 28,000 ha of grassland within the catchment is still required to attempt to address the erosion problem and move toward achieving some aspects of the desired state. There is an urgent need to effectively treat this 28,000 ha area, otherwise sediment yields will continue to increase, as unplanted gullies continue to grow in size.
- The majority of the highly erodible land under grassland within the Waiapu catchment is in private ownership (general and Māori title). Therefore, the uptake of treatment will be voluntary except in areas where it is required under the Gisborne Combined Regional

Land and District Plan (i.e. Land Overlay 3A). Unless further regulation is introduced to require effective treatment of areas of eroding and erosion-prone land not currently covered by Land Overlay 3A, the rate of uptake of existing incentive schemes (e.g. the East Coast Forestry Project) will need to be increased.

Social, cultural, & economic aspects

- The catchment and the people who depend on its resources have been subjected to a series of environmental, social, and economic shocks for over a century. These shocks have had impacts on the wellbeing of Ngāti Porou in the catchment and appear to have played a contributory role in the current low socio-economic profile for the area and a degradation of cultural values of importance to Ngāti Porou.
- Interventions to date, based on this brief and provisional assessment, have not fully addressed or embraced the aspirations of Ngāti Porou as far as can be assessed or reflected in their holistic view of the interconnectedness of the wellbeing of the community and environment — that the health of the river and the people are one.
- Any attempt to develop and implement interventions to address the erosion problem in the Waiapu catchment without the direct and active participation of Ngāti Porou (as mana whenua) and local communities is unlikely to be successful.
- In defining future courses of action and interventions to reduce the erosion and its effects, it should be recognised that they may lead to undesirable as well as desirable socio-economic and cultural impacts. Future proposed catchment management policies or erosion control programmes will therefore require careful environmental and social impact assessment and be informed by the perspectives, values, and experiences of Ngāti Porou.

Acknowledgements

We wish to thank MAF for providing the funding for this study and to the project Steering Committee for their feedback and guidance.

Many thanks to those who have assisted through the provision of data, information, and sharing their personal knowledge and experience: Randolph Hambling (MAF), Malcolm Penn (MAF), Trevor Freeman (GDC), and others. Also, a big thank you to Tui Warmenhoven and Pia Pohatu, and all others involved in the consultation processes for their time and input. Thanks to Tui for allowing us to use an image of some artwork used in Harmsworth et al. (2002) and a very big thank you to Georgina of Makarika School (at the time) who created the fantastic artwork. Thanks also to Statistics NZ for the timely provision of the census data.

We wish to acknowledge that the analysis of the gully dataset (owned by Landcare Research Ltd), the results of which have been used in this study, was undertaken by Landcare Research. Thanks to Les Basher and Alex Herzig (Landcare Research) for their assistance with this.

The assistance of G. Pearse and J. Skurupey with the analysis undertaken for Chapter 5 of the report is gratefully acknowledged.

Many thanks to Brenda Baillie (Scion) for undertaking a peer review of the report and thanks to Paul Charteris and Peter Clinton for their helpful comments and advice.

Appendices

Appendix 1: Vegetation type descriptions

Reproduced from Harmsworth et al. (2002).

Podocarp forest: Forest on or adjacent to floodplains and terraces. Dominated by podocarp trees and wetland vegetation. Podocarps include rimu, miro, totara, matai, and kahikatea. Kahikatea forest and wetland vegetation are common on floodplain and lower parts of terraces, where swamps and bogs are prevalent. Swamps are dominated by raupo, harakeke, and niggerhead. Kahikatea, ti (cabbage trees) and manuka occur on swamp fringes. Bogs are dominated by rushes, sedges, (Baumea *spp*., Juncus *spp*., wirerush) sphagnum moss. Bogs may also include manuka and Dracopyllum.

Lowland podocarp-broadleaved forest: Forest with emergent podocarps above a prominent canopy of broadleaved species. Generally occurring below the altitudinal limit of rimu (*Dacrydium cupressinum*), which is a common emergent. Podocarps in this class, in addition to rimu, include matai, miro, totara, Halls totara, kahikatea, tanekaha. Common broadleaved species include kamahi, rata, tawa, tairaire, pukatea, titoki, towai, hinau, rewarewa, maire.

Podocarp-broadleaved-beech forest

Forest with emergent podocarps above a prominent canopy of broadleaved species, and with irregular admixtures of lowland beech species. Occurs below the altitudinal limit of rimu (*Dacrydium cupressinum*).

Lowland beech forest: Forest with a canopy dominated by beech (*Nothofagus*) species, principally black, hard or red beech, and occurring below approximately 1,000m a.s.l. Silver beech may be present in some areas. The upper altitudinal range is approximately 1,200 m a.s.l. in the Raukumara Range.

Highland beech forest: Forest with a canopy dominated by beech (*Nothofagus*) species, principally silver and mountain beech, and occurring between approximately 1,000 m a.s.l. and the tree line. Minor species include red beech, broadleaf, bog pine, pink pine, and sub-alpine shrub species.

Scrubby forest and scrub with scattered fern: Scrubby vegetation (cleared and burnt) comprising manuka-kanuka, bracken, with coastal–broadleaved forest remnants. Scrub and shrubland dominated by manuka and bracken fern, with coastal-broadleaved forest remnants. Coastal forest characterised by specific broadleaved species with both coastal and wider distribution. Remnant coastal-broadleaved forest includes species such as pohutukawa, ngaio, karaka, puriri, kohekohe, and nikau. Shrubs and small trees included species of Coprosma, Myrsine, Pittosporum, and kawakawa. Ferns included tree fern, and fern spp. such as bracken, ring fern, prickly shield fern, water fern, and kiokio.

Manuka, Kanuka/Podocarp forest: Manuka, kanuka forest, scrub, and shrubland with remnants of Podocarp forest. An assemblage of manuka (*Leptospermum scoparium*), kanuka (*Kunzea ericoides*), and podocarp trees such as rimu, miro, totara, matai, and kahikatea. Broadleaved species are generally confined to the understory. Kahikatea forest and wetland vegetation are common on floodplain and lower parts of terraces, where swamps and bogs are prevalent. Swamps are dominated by raupo, harakeke, and *Carex secta*. Kahikatea, ti kouka (cabbage tree) and manuka occur on swamp fringes. Bogs are dominated by rushes, sedges, (Baumea *spp.*, Juncus *spp.*, wirerush) and some moss. Bogs may also include manuka and Dracopyllum.

Manuka, Kanuka scrub: Manuka, kanuka scrub and shrubland dominated by manuka (*Leptospermum scoparium*) or kanuka (Kunzea ericoides). Represents areas which have been cleared or burned and replaced by manuka and kanuka, from juvenile open shrubland to tall mature stands.

Sub-alpine scrub: Indigenous scrub communities occurring above the montane zone or confined above the treeline. These communities range from monospecific to highly diverse, but typically form dense assemblages less than 2.5 metres high. Characterised by species of the genera Olearia, Senecio, Coprosma, Hebe, Phormium, Houheria, and Dracophyllum.

Sand dune vegetation: Herbaceous vegetation, dominated by sand binding grasses or other herbaceous plants. Principal species included spinifex and pingao (indigenous).

Appendix 2: Definition of erosion types

Reproduced from Harmsworth et al. (2002).

The main erosion types identified by Jessen et al (1999) in the Waiapu catchment are summarised below.

Deposition: Deposition includes all boulders, gravels, sands, silt and mud, and other material such as logs, branches, etc., transported down the rivers and streams during high rainfall events and deposited after floods on floodplains and low terraces. Large areas of deposition were identified during field study and located on maps. A number of maps produced in this project show depositional and high and moderate flood risk areas.

Streambank: Stream or riverbank sides erode or sections collapse, depositing large amounts of sediment and bank material into the channel. Erodible streambank areas need various forms of protection to reduce land loss. Protection along stream and riverbanks include trees such as willows and native bush buffers, groynes, rock stabilisation walls.

Riparian slip: The term used for soil slips on steep slopes adjacent to streams and rivers, where soil and material are deposited directly into the stream or river. Usually activated during high intensity rainstorms or by undercutting of stream and river channels.

Earthflow: Large deep-seated areas of moving or creeping soil, subsoil, and rock materials. Earthflows are characteristic of certain landforms and rock type. They can on occasion represent large parts of hillsides moving down slope, and can move several metres each year. Earthflow can occur on gentle to steep slopes, usually on weak, fractured rock or rock with high clay content that becomes saturated with water. Water tends to lubricate the slope enabling it to move, and incorporation of water may be the result of rainfall, high water tables and springs, or high soil moisture levels in colluvial hill slope subsoils. Earthflows are often activated by stream undercutting at the base of a slope or as a consequence of material being added to the body of the earthflow (i.e. top-loading). Landforms associated with earthflows include hump-and-hollow topography, ponding, vertical cracking, and extensive areas of broken and irregular pasture.

Soil Slip (also referred to as shallow landslide): Soil slip is the most common form of landslide and consists of a slip scar and a debris tail. Slips are usually less than 1 metre deep and most occur on slopes steeper than 28 degrees (Lynn et al. 2009). They are generally triggered during storm events such as Cyclone Bola when between 10% and 25% of hillsides were affected by soil slip erosion. Soil slips result in the removal of topsoil. During large storms such as Cyclone Bola, about 50% of the displaced material is delivered to streams and waterways (Reid & Page 2002). The remaining sediment is stored on the landscape and in some cases delivered to streams via overland flow during subsequent storm events. Once removed, the rate of soil recovery on slip scars is slow with pastoral productivity returning to 80% of its original production state (rates of soil development vary from region to region) 60-years after the event (Lambert et al 1984) compared with a forest soil which generally takes between 100 and 1000 years to form.

Debris avalanche: A high energy and more rapid form of landslide but incorporating a greater proportion of debris and rock material. Debris avalanches usually occur on steep slopes on certain types of landform and rock type. During intense rainfalls they can remove large volumes of soil, weathered rock and vegetation and transport material very quickly for several kilometres. In the Waiapu catchment, debris avalanches are associated with greywacke, argillite and indurated sandstones in the mountainous upper parts of the catchment.

Slump: Slump erosion is a deep-seated form of mass movement resulting in the sudden failure of a large part of a hillside and contrasts with earthflows where displacement occurs over periods measured in months and years. Slumps fail by gravitational failure along a deep-seated and concave failure plane usually within unstable or deeply weathered materials.. The slumped block is displaced downward and outward to form a steep scarp at the head of the slump. Some very large slumps are triggered by earthquakes.

Sheetwash: The removal of surficial soil and organic material by running water during rainfall events that is sufficiently intense to generate surface runoff. Sheet erosion is very shallow and periodic rainfalls repeatedly move soil. Often occurs on steep dry slopes and can be associated with rock type and soil type. Sheet typically occurs on airfall tephra (volcanic ash), argillite and mudstone terrain.

Wind erosion: The transportation of fine-grained material by strong winds. Wind erosion is prevalent on sand dunes, beaches, coastal cliffs, and on inland areas with little vegetative cover. It is also common on braided river channels typically found in the Waiapu catchment. Wind erosion can cause dust problems especially around cultivated fields.

Rockfall: This occurs when unstable rock material on steep slopes falls away from the in situ rock mass. Rockfalls can be triggered by heavy rainfall, earthquake activity or by oversteepening particularly if materials are fractured or deeply weathered. Rockfalls typically occur on coastal cliffs and river or stream escarpments

Tunnel erosion: The formation of sub-surface tunnels by concentrated water draining along preferred drainage pathways. They typically form in soft materials such as volcanic ash where it overlies a harder substrate. Tunnel erosion is not common in the Waiapu catchment where the fractured substrate is highly permeable.

Gullies: Gullies start as small, incipient, typically linear, drainage pathways along which concentrated water erodes the surficial soil and underlying rock to form a channel. Incision into unstable rock material results in channel deepening with consequent destabilisation of adjacent side slopes which themselves fail by mass movement. Through this combination of hydraulic downcutting and associated mass movement, gullies enlarge over time to become amphitheatre-shaped. The crushed argillite and greywacke in the Tapuaeroa, Mangaoporo, and Mata sub-catchments (Map1) are particularly prone to gullying.

Appendix 3: River cross-section data

Appendices reproduced from Peacock, D.H. 2011. Waiapu River Catchment Study – river cross section data as benchmarking parameters. Consultancy Report. Peacock D.H. Limited.

Appendix 3.1: Tapuaeroa river benchmarking parameters

Cross section or Reach	Bench marking parameters	Circa 1969	Immediate Pre- Bola	Immediate Post-Bola	"Current" (2007)
19500m	Mean bed level (m):	187.06	186.88	188.09	n/a
	Change in MBL (mm/yr):	-60	-68	+172	n/a
	Active bed width (m):	97	101	101	n/a
16760m	Mean bed level (m):	164.08	164.78	165.27	167.83
	Change in MBL (mm/yr):	+12	-2	+178	+116
	Active bed width (m):	202	215	222	263
13290m	Mean bed level (m):	134.08	135.44	135.71	137.32
	Change in MBL (mm/yr):	+29	+32	+76	+151
	Active bed width (m):	205	230	237	250
9290m	Mean bed level (m):	107.80	108.09	108.66	109.12
	Change in MBL (mm/yr):	+100	+20	-30	+58
	Active bed width (m):	178	195	233	250
5830m	Mean bed level (m):	86.69	87.28	87.48	n/a
	Change in MBL (mm/yr):	+66	-5	+44	n/a
	Active bed width (m):	364	366	366	n/a
2270m	Mean bed level (m):	69.57	69.59	69.57	70.03
	Change in MBL (mm/yr):	-21	0	-28	+52
	Active bed width (m):	422	424	430	437

NOTES:

1. In the —Circa 1969" column, all MBL's are interpolated between the 1968 and 1970 (or 1972) surveys.
2. In the —Pre-Bola" column, MBL's are for the 1986 survey, and the aggradation/incision rates are for the period between the 1982 and 1986 surveys;
3. In the —Post- Bola" column, MBL's are for the 1988 survey and aggradation/incision rates are between the 1988 and 1993 surveys;
4. Mean bed levels for the —Current" column are from the 2007 survey, and the aggradation/incision rates are between the 2003 and 2007 surveys.

Appendix 3.2: Raparapaririki river benchmarking parameters

Cross section or Reach	Bench marking parameters	Circa 1969	Pre- Bola (1987)	Post Bola	"Current" (2007)
3379m	Mean bed level (m):	n/a	248.13	n/a	281.10
	Change in MBL (mm/yr):		543	2070	-48
	Active bed width (m):		33	n/a	210
2915 to 3379m:	Volume deposited (m3/m/yr):		5.9	355	n/a
2915m	Mean bed level (m):		238.84	n/a	267.02
	Change in MBL (mm/yr):		243	3184	-185
	Active bed width (m):		50	n/a	181
2579 to 2915m:	Volume deposited (m3/m/yr):		1.6	300	-64.1
2579m	Mean bed level (m):		229.79	n/a	257.13
	Change in MBL (mm/yr):		-95	2830	-59
	Active bed width (m):		45	n/a	202
2211 to 2579m:	Volume deposited (m3/m/yr):		0.9	206	-19.4
2211m	Mean bed level (m):		222.37	n/a	247.51
	Change in MBL (mm/yr):		342	2343	-13
	Active bed width (m):		28.4	n/a	136
1913 to 2211m:	Volume deposited (m3/m/yr):		5.2	138	-20.3
1913m	Mean bed level (m):		217.26	n/a	239.42
	Change in MBL (mm/yr):		419	1966	-84
	Active bed width (m):		46	n/a	146
1497 to 1193m:	Volume deposited (m3/m/yr):		9.2	167	-8.9
1497m	Mean bed level (m):		210.68	n/a	228.53
	Change in MBL (mm/yr):		465	1343	26
	Active bed width (m):		76	n/a	238
1049 to 1497m:	Volume deposited (m3/m/yr):		10	139	24.2
1049m	Mean bed level (m):		203.19	n/a	217.35
	Change in MBL (mm/yr):		290	974	50
	Active bed width (m):		76	n/a	210
668 to 1049m:	Volume deposited (m3/m/yr):		12.2	71	40.9
Cross section or Reach	**Bench marking parameters**	**Circa 1969**	**Pre- Bola (1987)**	**Post Bola**	**"Current" (2007)**
668m	Mean bed level (m):	n/a	197.46	n/a	209.09
	Change in MBL (mm/yr):		640	606	75
	Active bed width (m):		64	n/a	234.5
100 to 668m:	Volume deposited (m3/m/yr):		13	51	29.2
100	Mean bed level (m):	n/a	188.36	n/a	196.21
	Change in MBL (mm/yr):		189	398	13
	Active bed width (m):		140	n/a	193
0 to 100m:	Volume deposited (m3/m/yr):		n/a	n/a	n/a

NOTES:

1. In the —Pre-Bola” column, mean bed levels are for the Feb 1987 survey, and the aggradation/incision rates are for the period between the 1984 and 1987 surveys;
2. In the —Post- Bola” column, aggradation/incision rates are between 1987 (pre-Bola) and 1994 (post-Bola) surveys; except at 3379m where the rate is for the period 1987 to 2003.
3. Mean bed levels for the –Current” column are from the 2007 survey, and the aggradation/incision rates are between 2007 and 2010 surveys; except at 3379m which is between 2003 and 2007 surveys.

Appendix 3.3: Mangaoporo river benchmarking parameters

Cross section or Reach	Bench marking parameters	Circa 1969	Immediate Pre- Bola	Immediate Post-Bola	“Current” (2007)
12530m	Mean bed level (m):	170.40	172.18	172.24	n/a
	Change in MBL (mm/yr):	+21	+166	+22	n/a
	Active bed width (m):	170	182	220	n/a
10630m	Mean bed level (m):	139.96	140.44	140.86	141.47
	Change in MBL (mm/yr):	+24	-21	-9	+58
	Active bed width (m):	205	210	220	*166
7850m	Mean bed level (m):	108.78	109.33	109.91	109.98
	Change in MBL (mm/yr):	+49	-63	-69	+66
	Active bed width (m):	52	58.5	60	62
4460m	Mean bed level (m):	77.77	78.37	78.09	78.31
	Change in MBL (mm/yr):	+47	+61	+50	-51
	Active bed width (m):	64	57.5	57.5	69.7
2270m	Mean bed level (m):	58.57	59.19	59.54	59.43
	Change in MBL (mm/yr):	+8	+20	-37	-18
	Active bed width (m):	129	130	130	127.5
1450m	Mean bed level (m):	51.24	51.80	51.96	52.21
	Change in MBL (mm/yr):	+39	-11	-1	-5
	Active bed width (m):	297	297	297	290

NOTES:

1. In the ―Circa 1969” column, all MBL‘s are interpolated between the surveys either side of 1969, and the aggradation/incision rates are for the period between the surveys either side of 1969.
2. In the ―Pre- Bola” column, MBL‘s are for the 1985 survey, and the aggradation/incision rates are for the period between the 1982 and 1985 surveys;
3. In the ―Post- Bola” column, MBL‘s are for the 1988 survey and aggradation/incision rates are between the 1988 and 1994 surveys;
4. Mean bed levels for the ―Current” column are from the 2007 survey, and the aggradation/incision rates are between the 2002 (or 2003) and 2007 surveys.
5. A side stream fan has intruded into the active bed at 10630m in 2007, (marked with *), effectively reducing the bed width, but may have also affected the MBL.

Appendix 4: Gully numbers, area, & size for Waipau sub-catchments for 1957, 1997, & 2008

Data generated by Landcare Research.

Sub-catchment	Year	# gullies	Area (ha)	# < 5 ha	# 5-15 ha	# > 15 ha	# Cretaceous	Cretaceous (ha)	# Tertiary	Tertiary (ha)
Tapuaeroa	1957	415	557.8	393	21	1	386	497.6	29	60.3
Tapuaeroa	1997	277	1439.6	203	48	26	260	1314.2	17	125.4
Tapuaeroa	2008	231	1325.1	162	44	25	219	1203.1	12	122.0
Mangaoporo	1957	83	263.4	65	17	1	82	262.7	1	0.6
Mangaoporo	1997	62	391.5	35	20	7	62	391.5	0	0
Mangaoporo	2008	45	309.2	25	14	6	45	309.2	0	0
Poroporo	1957	75	78.5	74	1	0	52	61.4	23	17.1
Poroporo	1997	10	39.0	7	3	0	6	31.8	4	7.2
Poroporo	2008	7	29.0	5	2	0	5	25.5	2	3.5
Maraehara	1957	67	80.9	64	3	0	38	60.6	29	20.3
Maraehara	1997	15	28.7	14	1	0	4	6.5	11	22.2
Maraehara	2008	12	23.9	11	1	0	1	1.7	11	22.2
Waiapu (Ruatorea)	1957	89	95.8	88	1	0	49	65.8	40	30.0
Waiapu (Ruatorea)	1997	27	69.7	22	5	0	17	44.6	10	25.1
Waiapu (Ruatorea)	2008	14	37.9	12	2	0	5	13.5	9	24.4
Makatote	1957	55	76.7	53	2	0	53	75.9	2	0.8
Makatote	1997									
Makatote	2008									
Makarika	1957	91	155.9	88	3	0	69	123.9	22	32.0
Makarika	1997	31	97.4	26	4	1	25	88.6	6	8.7
Makarika	2008	24	77.0	20	3	1	21	74.2	3	2.8
Ihungia	1957	118	252.6	108	8	2	30	96.0	88	156.6
Ihungia	1997	70	232.8	57	11	2	11	81.5	59	151.3
Ihungia	2008	16	80.0	12	2	2	2	53.0	14	27.1
Upper Mata	1957	226	567.2	201	19	6	50	158.9	176	408.3
Upper Mata	1997	299	1046.6	242	43	14	39	127.0	260	919.6
Upper Mata	2008	203	803.5	159	32	12	28	80.7	175	722.8
Waitahaia	1957	63	207.5	48	12	3	63	207.5	0	0
Waitahaia	1997	81	281.4	66	14	1	81	281.4	0	0
Waitahaia	2008	73	225.5	60	13	0	73	225.5	0	0
Lower Mata	1957	174	283.2	159	14	1	173	280.2	1	3.0
Lower Mata	1997	86	252.1	69	15	2	86	252.1	0	0
Lower Mata	2008	50	147.5	40	10	0	50	147.5	0	0
Waingakia	1957	12	11.4	12	0	0	12	11.4	0	0
Waingakia	1997	8	14.2	8	0	0	8	14.2	0	0
Waingakia	2008	8	14.2	8	0	0	8	14.2	0	0
Kopuaroa	1957	19	40.3	17	2	0	19	40.3	0	0
Kopuaroa	1997									
Kopuaroa	2008									
Mangapoi	1957	30	31.1	29	1	0	30	31.1	0	0
Mangapoi	1997	31	195.5	20	6	5	31	195.5	0	0
Mangapoi	2008	31	195.5	20	6	5	31	195.5	0	0
Mangawhairiki	1957	27	18.0	27	0	0	27	18.0	0	0
Mangawhairiki	1997	14	57.6	11	1	2	14	57.6	0	0
Mangawhairiki	2008	14	57.6	11	1	2	14	57.6	0	0
Raparaparirki	1957	62	69.8	58	4	0	62	69.8	0	0
Raparaparirki	1997	56	402.4	39	9	8	56	402.4	0	0
Raparaparirki	2008	43	364.8	27	8	8	43	364.8	0	0
Weraamaia	1957	20	52.0	17	3	0	20	52.0	0	0
Weraamaia	1997	5	22.5	2	3	0	5	22.5	0	0
Weraamaia	2008	1	5.0	0	1	0	1	5.0	0	0

Increasing trend	Significantly increasing
Decreasing trend	Significantly decreasing

Appendix 5: Policy document scan

The following erosion control-related policies are summarized here:

- East Coast Forestry Project (ECFP).
- Sustainable Land Management (Hill Country Erosion) Programme (HCEP).
- Sustainable Land Management (Hill Country Erosion) Programme (HCEP).
- Afforestation Grants Scheme (AGS).
- National Policy Statement on Freshwater Management 2011 (NPSFM).
- Gisborne District Council Combined Regional Land and District Plan, Chapter 6, Soil conservation.

East Coast Forestry Project (ECFP)

Definition

The ECFP is a national policy administered by the Ministry of Agriculture and Forestry and developed under the government's sustainable land use policies. It is a grant scheme established in 1992 with government endorsement and approved funding until 2020 (MAF, 2011).

Purpose

It has a primary goal of sustainable land management, targeting the worst 60,000 hectares of eroding land solely in the Gisborne District. Targeting of land is supported by rules in the Gisborne District Council's Regional Land and District Plan. This goal was revised by cabinet in 1999 and reconfirmed in a subsequent review in 2005 (MAF, 2011).

Sustainable Land Management (Hill Country Erosion) Programme (HCEP)

Definition

The HCEP is a national policy administered by the Ministry of Agriculture and Forestry and developed under the government's sustainable land use policies. It operates as a partnership among central Government, four regional councils (including but not limited to Taranaki, Greater Wellington, Horizons, Hawke's Bay, Gisborne) and associated landowners. It has been described as a ten year programme having been operational since 2007/08, with Horizons programme in its fourth year, three other councils coming to the end of their second of eight years and Gisborne in its first year (MAF, 2011).

Purpose

The Ministry of Agriculture and Forestry's stated goal is “to increase the rate of protection of the North Island hill country pasture with a severe or extreme erosion risk” (MAF, 2010).

Permanent Forest Sinks Initiative (PFSI)

Definition

The PFSI is a national policy administered by the Ministry of Agriculture and Forestry and developed under the government's climate change policies (MAF, 2011).

Purpose

The PFSI is similar to the New Zealand Emissions Trading Scheme (ETS) in allowing landowners to realise the value of carbon sequestration through the provision of credits but aims at establishing permanent forests. It fills a niche that the ETS does not by providing a small-scale mechanism for landowners who are more risk averse. The programme is not time bound, but has been in operation for over 3 years, having begun in 2007/08. It does not involve Government grant funding but instead provides landowners with internationally tradable Assigned Amount Units (AAUs) for entering into a covenant with Crown for at least 50 years (MAF, 2011).

Afforestation Grants Scheme (AGS)

Definition

The AGS is a national policy administered by the Ministry of Agriculture and Forestry and developed under the government's climate change policies (MAF, 2011).

Purpose

The purpose is, primarily to encourage the planting of Kyoto compliant forestry through the provision of grants. However, priority is given to afforestation proposals that also reduce the risk of erosion, improve water quality, and indigenous biodiversity. The scheme operates through a tendered public grant pool and a fixed regional grant pool (MAF, 2011).

National Policy Statement on Freshwater Management 2011 (NPSFM)

Definition

The NPSFM is an instrument under the Resource Management Act 1991 (RMA). The NPSFM must be interpreted and given effect to within the context of the RMA (MfE, 2011).

Purpose

There are three stated objectives in the policy (MfE, 2011):

1. “To safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water, in sustainably managing the use and development of land, and of discharges of contaminants”.
2. “To safeguard the life-supporting capacity, ecosystem processes and indigenous species including their associated ecosystems of fresh water in sustainably managing the taking, using, damming, or diverting of fresh water”.
3. “To improve integrated management of fresh water and the use and development of land in whole catchments, including the interactions between fresh water, land, associated ecosystems and the coastal environment”.

Gisborne District Council Combined Regional Land and District Plan, Chapter 6: Soil conservation

Definition

The purpose of the preparation, implementation, and administration of the Draft Combined Regional Land and District Plan is to assist the Gisborne District Council in carrying out its functions in the sustainable management of natural and physical resources within the Gisborne district under the Resource Management Act 1991. Within the plan conditions are set out that must be met and adhered to for consents to be granted so that an activity can begin or continue that will affect local, regional or national environmental conditions (GDC, 2003).

Purpose

To encourage land use practises that avoid, remedy or mitigate adverse effects of erosion on the environment by rehabilitation and stabilisation of eroded and erosion prone land, and changing poor management systems (GDC, 2003).

References

GDC, 2003. GDC, 2003. Proposed Combined Regional Land & District Plan (http://www.gdc.govt.nz/PlansAndReports/ CRLDP.htm).

MAF, 2010. Review of MAF afforestation schemes discussion documents 2010, Ministry of Agriculture and Forestry, New Zealand Government, Wellington.

MAF, 2011. Review of MAF Afforestation Schemes: Permanent Forest Sink Initiative; Afforestation Grant Scheme; East Coast Forestry Project; Sustainable Land Management (Hill Country Erosion) Programme. MAF Information Paper No: 2011/07.

MfE, 2011. National Policy Statement for fresh water Management 2011. Ministry for the Environment, New Zealand Government, Wellington.

Appendix 6: Glossary of Māori and Ngāti Porou terms

Glossary of Māori and Ngāti Porou terms and explanations (He Kupu Māori) reproduced from Harmsworth and Warmenhoven (2002).

Ahuwhenua - Agriculture

Atua - God, supernatural being

Awa - River or stream

Awaawa - Streams

Hapu - Sub-tribe, organised kin group, extended families, pregnant, impregnated

Hi ika - Fishing

Ira Tangata - Life principle for people, of mortals

Iwi - Tribe, people, large socio-political grouping, bone

Kaitiaki, Kaitieki - Agents to provide guardianship of the environment

Kaitiekitanga - Concept of guardianship or stewardship of the environment

Kapata Kai - Food cupboard, used for reference to food sources, bush, sea, rivers, etc.

Karakia - Prayer

Kaumatua - Elder, respected elder

Maara - Cultivations

Maangoingoi - Fishing

Mahinga kai - Areas for cultivation or resource collection

Mana - Prestige, authority, status

Manaaki - Care for, host, hospitality, look after

Manaakitanga - Generosity, kindness

Manga - Tributary or stream

Mana Motuhake - Sovereignty, authority, autonomy

Mana Whenua - Authority over land, region, or district

Maunga - Mountain, sacred peak, high point, tipuna

Marae - Area at front of meeting house, social gathering place, social centre

Matauranga - Traditional knowledge

Mauri - A life force, permeates in all living things, sustains life

Moteatea - Chants depicting significant historical statements

Ngahere - Forest

Nga ngarara - Insects, small land creatures

Noa - Free from tapu, unrestricted

Oranga - Wellbeing, Health

Otaota - Plants

Paa - Fortified settlement

Papa kainga - Ancestral land, community areas for housing, cultivation etc.

Papatuanuku - The earth mother

Pepeha - Proverb, saying

Puuraakau - Historical stories

Rahui - Restrictions, regulations, usually to protect or sustain resources

Rakau - Tree

Ranginui - The sky father

Rapu tuna - Eeling

Raranga - Traditional weaving

Reo - Voice, language

Rongoa - Traditional medicinal practice, medicines from plants

Tane - Male, man

Tangaroa - God of the sea, the sea and all sea creatures

Tangata - Man, person; plural tangata: people

Tangata whenua - People of the land, or people from the land

Tapu - Sacred, under divine protection

Tiaki - Guard, protect

Tipuna - Ancestor

Tikanga - Protocol, values, etiquette, custom, unspoken rules, truth, plan, correct way

Tohunga - Expert, person with specialist knowledge, skills

Toitu - Permanence, sustainability

Tuna - Eels

Wahi tapu - Sacred place

Wai - Water

Wairua - Spiritual dimension

Waiata - Song

Wananga - Traditional learning, schools of learning

Whanau - Family, birth, extended family

Whanaungatanga - Family, collectively, kinship

Whakapapa - Genealogy, decendency, links to all living things

Whakatauaki - Proverb, saying

Whenua - Land, placenta, afterbirth

Appendix 7: Details of the census meshblocks in the Waiapu catchment (using the 2001 Statistics New Zealand map-base)

Meshblock Number	Parent Area Unit	Number of usual residents in 2006	Number of households in 2006	NZ Deprivation Index score in 2006
1343300	East Cape	45	18	9
1343700	East Cape	93	21	10
1343900	East Cape	96	33	10
1344000	East Cape	18	3	10
1344100	East Cape	15	3	10
1344200	East Cape	18	6	10
1344300	East Cape	0	0	10
1344400	East Cape	18	6	10
1344500	East Cape	42	15	10
1344600	East Cape	30	12	10
1344700	East Cape	42	15	10
1344800	East Cape	21	9	10
1344900	East Cape	24	9	10
1345000	East Cape	24	6	10
1345100	East Cape	12	3	10
1345200	East Cape	66	21	10
1345500	East Cape	0	0	10
1345600	East Cape	18	6	10
1345700	East Cape	21	6	10
1345801	East Cape	39	9	10
1345802	East Cape	3	3	10
1345900	Ruatoria	30	12	10
1346000	East Cape	21	9	10
1346100	East Cape	21	6	10
1346200	Ruatoria	18	6	10
1346301	Ruatoria	114	39	10
1346302	Ruatoria	69	24	10
1346401	Ruatoria	48	15	10
1346402	Ruatoria	237	60	10
1346500	Ruatoria	120	36	10
1346600	Ruatoria	9	0	10
1346700	Ruatoria	78	24	9
1346800	Ruatoria	27	9	9
1346900	East Cape	39	12	9
1347000	East Cape	27	9	9
1347100	East Cape	48	12	9
1347200	East Cape	69	21	10
1347300	East Cape	21	9	10

1347400	East Cape	36	9	10
1347500	East Cape	27	9	9
1347600	East Cape	78	27	9
1347700	East Cape	42	9	9
1347800	East Cape	42	15	10
1347900	East Cape	0	0	9
1348000	East Cape	24	6	10
1348100	East Cape	27	12	10
1348200	East Cape	27	15	10
1348300	East Cape	9	6	10
1348400	East Cape	9	0	10
1348500	East Cape	9	3	10
1348600	East Cape	9	3	8
1348700	East Cape	45	18	10
1348800	East Cape	78	21	9
1348900	East Cape	3	0	9
1349000	East Cape	12	3	8
1349100	East Cape	0	0	8
1349201	East Cape	30	12	8
1349202	East Cape	6	0	8
1349203	East Cape	6	3	8
1349300	East Cape	9	0	9
1349400	East Cape	24	9	8
1350601	East Cape	42	15	10
1350602	East Cape	0	0	10
1356600	Wharekaka	69	21	8
Total for catchment		**2304**	**723**	

Appendix 8: Meshblock boundaries

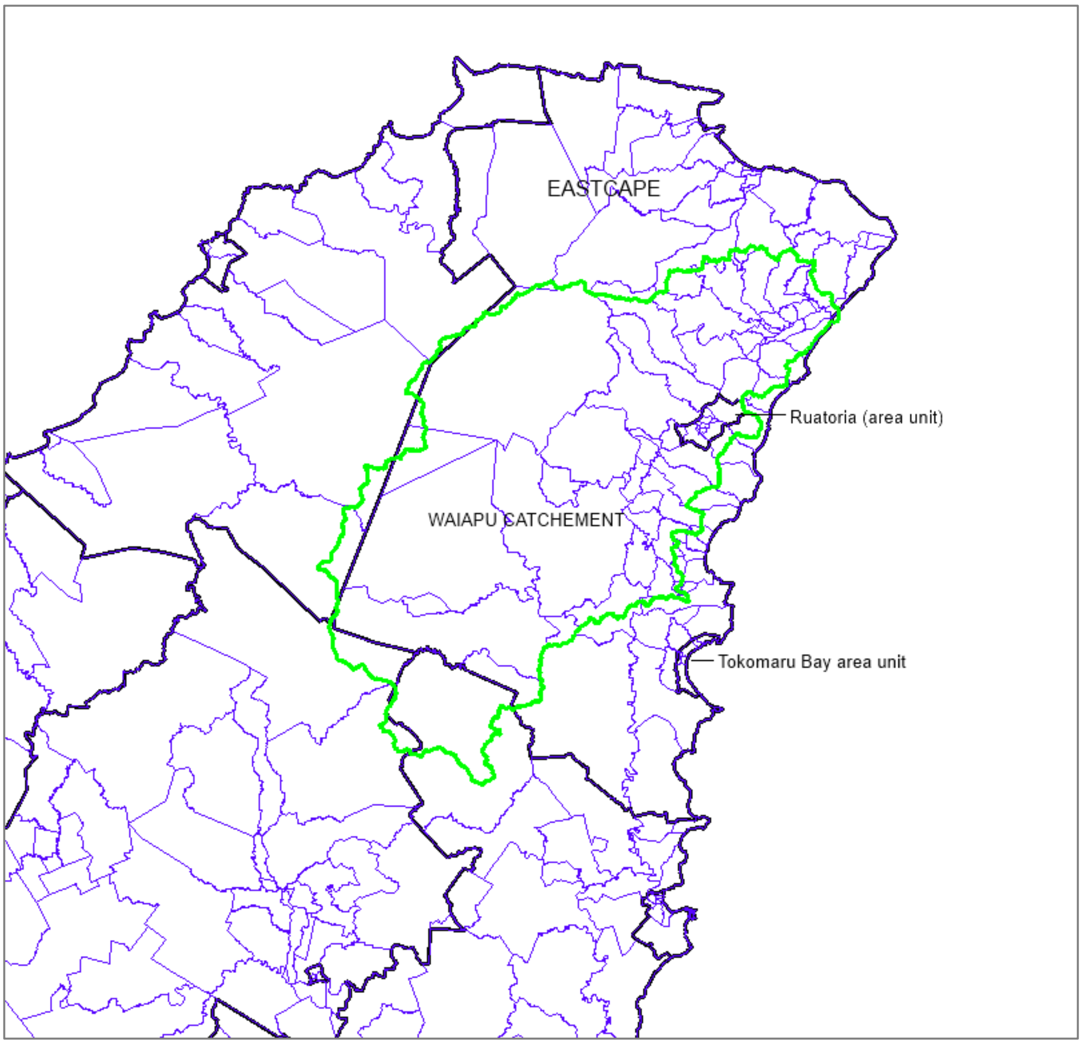

Figure A9-1. Waiapu catchment meshblocks.

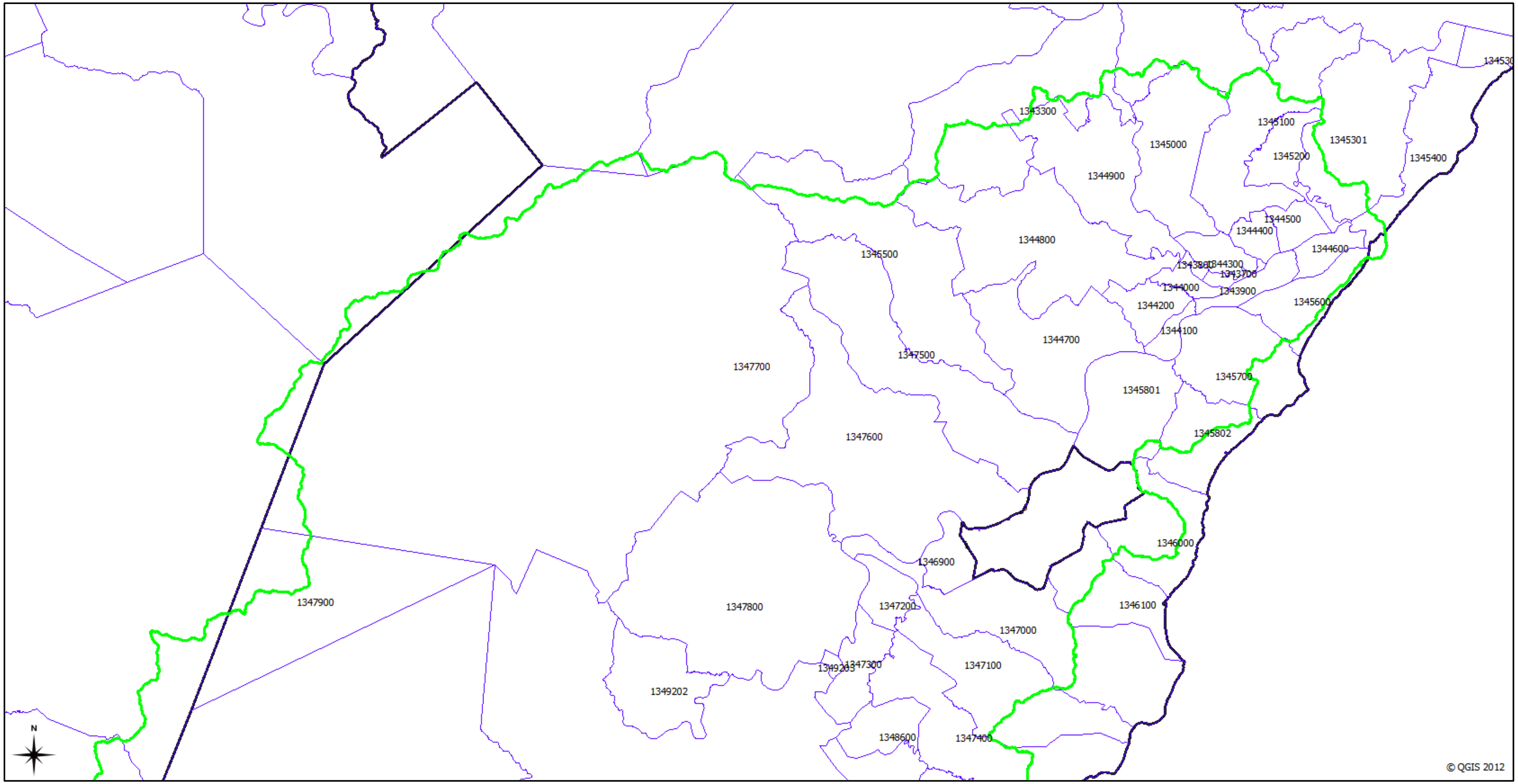

Figure A9-1a. The location of each meshblock in the northern part of the catchment area.

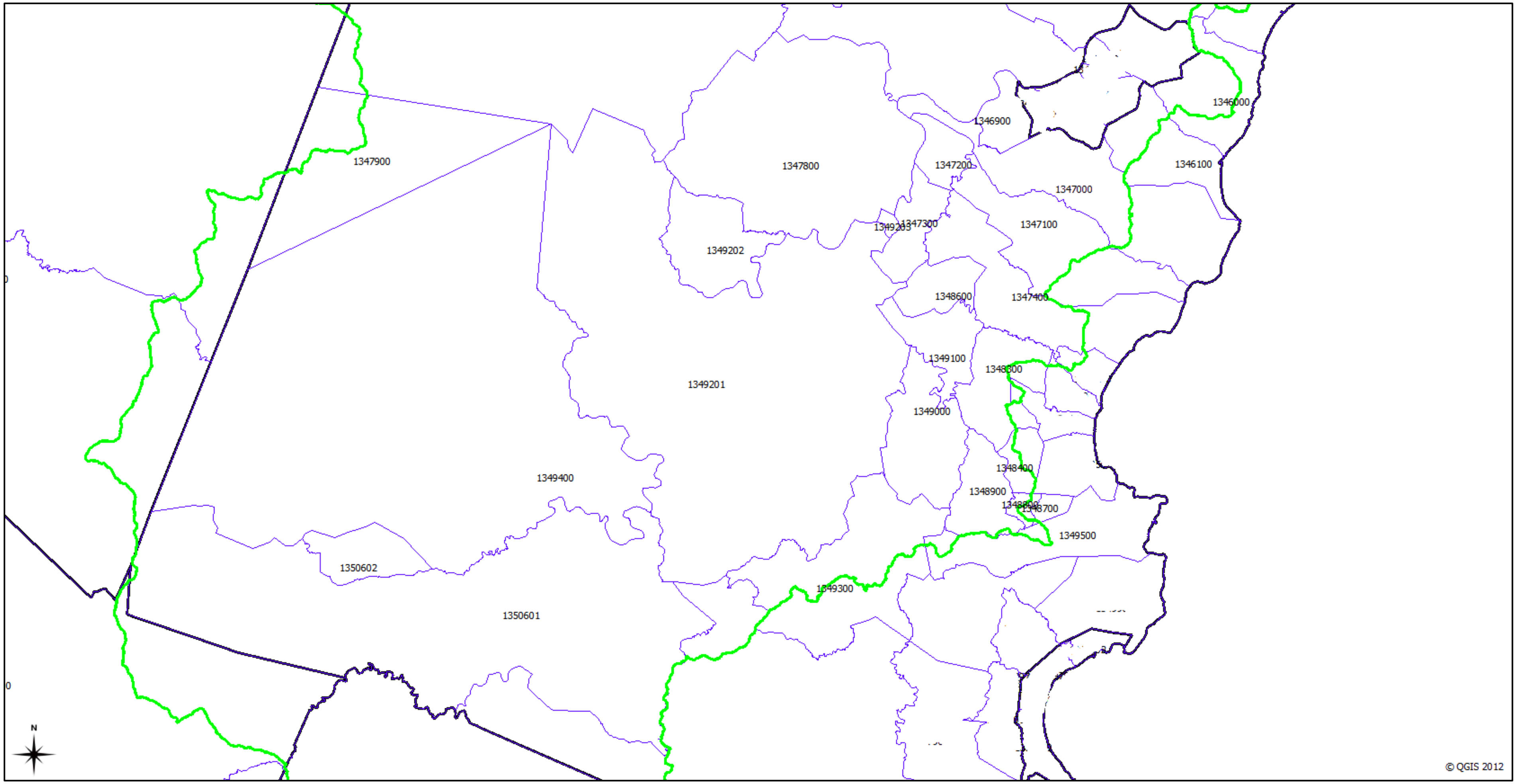

Figure A9-1b. The location of each meshblock in the southern part of the Waiapu catchment area.

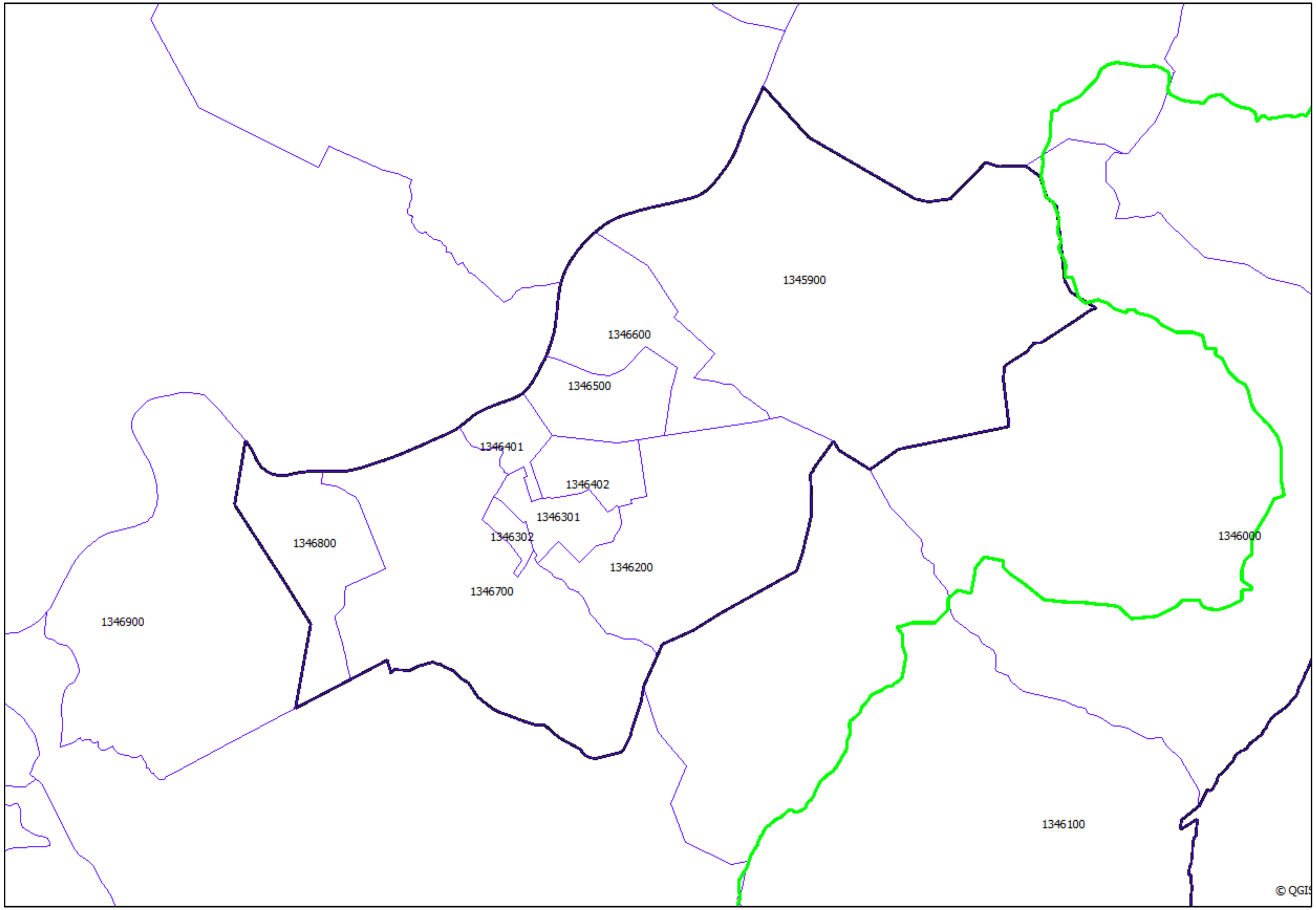

Figure A9-1c. The Location of the meshblocks in the Ruatoria area unit.

Appendix 9: Indicators of a desired state of the catchment

"This fulla first time he had bought a new tractor in the Waiapu Valley and he was showing off. He was saying to his mate, you need to buy a tractor, never mind the horse, too slow. Next day he tells his mate to get rid of this horse again. The mate with the horse says, „yes I know it's slow, but while the mule might be slow, the earth is patient[1]".

Criterion 1: Ngāti Porou and the Waiapu and its Catchment

"We want our people, our tamariki, Ngāti Porou and our children generally to understand. At the moment what do we tell them about the Waiapu? So it's about having an education programme so they are learning the tikanga and what the Waiapu means to us because I think there may be some younger generations that think, „Oh its only water'. They think it is just like any other river, but it's not like any other river[2]."

DESIRED STATE: "HUI NOA HUI NOA TE MAUNGA WHAKAHII, KEI WHEA TE IWI? THE MAJESTIC MOUNTAIN SEARCHED THE VALLEY BELOW AND ASKED, WHERE ARE THE PEOPLE?[3]"

Category		Indicator
Demographics *"We want our people, our tamariki, Ngāti Porou and our children generally to understand[4]."*	i.	Numbers and age profiles of Ngāti Porou Whanau living in the Waiapu catchment.
	ii.	Ngāti Porou knows who our people are and where they reside as well as their demographic status to inform planning.
Socio-Economic *"The river is sick so we are sick.[5]"*	iii.	All Ngāti Porou have a job opportunity in the Waiapu catchment.
	iv.	Ngāti Porou are never hungry and can feed themselves and their whanau from the land. *"We want to get back to fishing and catching whitebait by the bucketful[6]."*

[1] (Maro pers comm. 2011)
[2] (Collier pers comm. 2011)
[3] (Harmsworth et al., 2002)
[4] (Collier pers comm. 2011)
[5] (Harmsworth et al., 2002)
[6] (Maro pers comm. 2011)

	v.	Investment fund for Ngāti Porou small to medium businesses (SME's) established focused on sustainable land use established in the Waiapu catchment (note that the business case and implementation plan will be aligned with accepted business practice and Ngāti Porou tikanga).
	vi.	Ngāti Porou are involved in leveraging the best finance options for its people for housing and looking at innovative ways to fund its home builds in the Waiapu catchment.
	vii.	Ngāti Porou own their own homes in the Waiapu catchment.
	viii.	Poverty is eradicated in the Waiapu catchment.
Health *Most of the knowledge (of Rongoa) and experts came or resided in the Maraehara catchment, this was attributed to the regenerated forest there. They had the knowledge base because of the forest."*[1]	ix.	Ngāti Porou have health statistics that exceed that of non-Māori in Aotearoa.
	x.	Cultural inventory of rongoa species found in the Waiapu catchment complete and monitored.
	xi.	Areas of harvesting for rongoa are not negatively affected by erosion.
Education *We need to sit down our young people and get them to listen. A few hours is not enough there are very few of us left that can talk. There is a lot of nursery work to be done. We need to be the conscience of the river and to be positive about the river. Only then can we keep our streams clear. To have our river back to where it should be we need to work on ourselves*[2].	xii.	Ngāti Porou awards, scholarships and internships for students in the areas of resource management particularly in erosion related fields established.
	xiii.	Ngāti Porou has access to environmental and other land-use advice and information which supports the aspiration of Ngāti Porou for their land.
	xiv.	All advisors that are non-Ngāti Porou will have clear knowledge transfer requirements in their service agreements to Ngāti Porou to build internal capacity.
	xv.	Ngāti Porou students currently studying with tertiary providers in areas relevant to the Waiapu catchment are identified and recruited to understand their skills and align these to restoration projects in the catchment.
	xvi.	Ngāti Porou who have specific skills pertaining to the Waiapu catchment and are currently in the workforce are identified and recruited to understand their skills and align these to restoration projects in the catchment.
	xvii.	Gaps are identified in skills and expertise for Ngāti Porou for the Waiapu and strategies in place to grow capability and capacity.

[1] (Warmenhoven pers comm. 2011)
[2] (Maro pers comm. 2011)

Leadership *"We need to talk to our young about what they see. We need to give them the opportunity. It is about how we role model, if they see me throw my rubbish over the bank[1]".*	xviii.	Effective Ngāti Porou succession programmes established in Marae, Hapu, Iwi, trusts and incorporations including associate trustee positions, Tuakana/Teina models and intern positions.
Recreation *"There are still areas you can swim but you don't know what you are swimming in![2]"*	xix.	Traditionally recorded swimming areas used by Ngāti Porou Whanau again.
	xx.	All schools are using the Waiapu for swimming and other recreational activities.
	xxi.	There are three Ngāti Porou events held on the Waiapu annually.
	xxii.	Surface water activities carried out by Ngāti Porou on the Waiapu regularly.
	xxiii.	River crossings are common to meet with neighbours.
	xxiv.	No adverse health effects from swimming in the waters of the Waiapu catchment.
Communication *"You used to be able to talk to your neighbours and now you can't hear them[3]."*	xxv.	All Ngāti Porou are aware of the issues facing the Waiapu and its ahi ka and are engaged in its restoration.
	xxvi.	Whanau in Tikitiki can speak across the river to the whanau at Te Horo without yelling.
Infrastructure *"Roads? What roads? Tracks more like it![4]"*	xxvii.	Ngāti Porou communities are no longer isolated due to land slips and/or road closures.
	i.	Ngāti Porou have efficient, safe and environmentally friendly waste disposal services within Ngāti Porou that do not negatively affect the Waiapu.
	xxviii.	Ngāti Porou have decision making influence on where and how roads are situated and managed in the catchment.

[1] (Collier pers comm. 2011)
[2] (Kaa pers comm. 2011)
[3] (Maro pers comm. 2011)
[4] (Kaa pers comm. 2011)

Criterion 2: Ngāti Porou - Environmental Indicators

"It is the biggest environmental disaster that Waiapu River. I am so much concerned about our maunga Pohautea. That is a maunga tapu of both sides of the river…and I say in twenty years there will be no Pohautea because of the erosion. That is a big concern for me and the old fullas. In my time on this earth, Pohautea. The erosion has been eating away at it. Erosion is all around the river. Work has to be done in the headwaters."[1]

DESIRED STATE: "When some of our nannies were still alive, they would talk about the river like the river itself is alive. It's a person"[2].

Category		Indicator
Kapata Kai *There is no kai left in the river, bugger all. People still go. People go out with the seasons. There is a time for fish. The fish still migrate but not as plentiful because there is no habitat. Our young guys are still eeling. They are going further up. Most of the pakeke have had areas destroyed, tuna, whitebait. You can't get down to the river, and the rocks that indicated certain species are gone*[3].	i.	Tuna and other kai is bountiful in the river and can easily regularly sustain Whanau and supply tribal events.
	ii.	There are several types of puha growing and harvested for whanau sustenance and tribal hui.
	iii.	Inanga can be harvested sustainably by the _bucket full'[4].
	iv.	Kokopu are part of the staple diet of Ngāti Porou again.
	v.	Watercress is plentiful and safe to eat.
	vi.	A broad range of non-cultivated foods are easily identifiable and part of the regular diet of Ngāti Porou in the catchment.
	vii.	The four species of Pekapeka are commonly found in native forests in the Waiapu catchment.
	viii.	Kereru and Kaka are found at similar numbers as in 1936 in the Poroporo catchment and the Waiomatatini/Northern Waiapu area.
	ix.	Weka are found in the Waiapu catchment.
	x.	Kapata kai areas are no longer negatively affected by erosion.
Water *"We haven't got clean water, it is totally unsafe and sadly the Kahawai have seemed to have packed up and left*[5]*".*	xi.	Underground springs are used and protected.
	xii.	Water quality from the Waiapu is to a standard where it is clean enough to drink.
	xiii.	Water quantity is sufficient for both economic and cultural activities.
Climate *"We cannot control the climate we cannot change the*	xiv.	Ngāti Porou are engaged in climate change adaptation activities to increase their resiliency to extreme weather events.

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[1] (Atkins pers comm. 2011)
[2] (Maro pers comm. 2011)
[3] (Maro pers comm. 2011)
[4] (Maro pers comm. 2011)
[5] (Kaa pers comm. 2011)

weather"[1].	i.	Traditional climate indicators are widely understood by Ngāti Porou.
Ngahere *"Native has got to go right through here. Pine is ok in its own place, not everywhere. We are not getting any of the money from forestry. We want manuka, kanuka, flax*[2]*".*	xv.	Large expanses of Ngāti Porou lands are in reserves for native forestry.
	xvi.	Nga Whenua Rahui and carbon agreements are widely established in the Waiapu catchment.
	xvii.	Afforestation is the core business of Ngāti Porou.
	xviii.	We are sustainably managing harvesting to avoid mass deforestation and have a managed system.
Land *"…30 acres lost on my farm. The flats are gone. Bridges are being replaced. All of the land was lost after Bola. Every bridge up the river was affected with Bola and the 1938 flood, with the large volumes of water*[3]*".*	xix.	The areas of Ngāti Porou land lost or seriously degraded over time by land use have substantially reduced from 1988 numbers.

[1] (Paenga pers comm. 2011)
[2] (Maro pers comm. 2011)
[3] (Paenga pers comm. 2011)

Criterion 3: Ngāti Porou - Cultural Indicators

"Our leadership needs to carry the kōrero that it is not about erosion. This is about the disconnection from the Waiapu. It is about the loss of our culture, our whenua and our river. Erosion is just a symptom of our loss of the holistic view.[1]"

DESIRED STATE: " HOAKE TAUA KI TE WAIAPU TATARA E MARU ANA – LET US GO TO THE WAIAPU WHERE THE RAIN CAPE IS THICK"

Category		Indicator
Matauranga Māori *"It's got umpteen names. There's Waipau koka huhua. There is a magnificent new poi that Hinetu Ngarimu wrote for her women's group, and it is all about the river and its history and the whakatauki, so you know this is significant to people's cultural kōrero[2]."*	ii.	Ngāti Porou have retained and use matauranga Māori as it pertains to growing and maintaining traditional and non-traditional crops.
	iii.	Records established and maintained to record matauranga Ngāti Porou and are accessible to Ngāti Porou
	iv.	Kapata Kai knowledge is taught in wananga to Ngāti Porou.
	v.	Number of tohunga and people who know matauranga Māori are easily identified and growing annually.
	vi.	Ngāti Porou pae are full each time the marae is used.
	vii.	Practitioners of Matauranga Ngāti Porou are promoted and honoured by ensuring they are engaged in all Waiapu Projects.
	viii.	Vehicles for the transfer of Matauranga Ngāti Porou are available to all Iwi members.
	ix.	A definitive history of Ngāti Porou and the Waiapu is completed.
	x.	With the restoration of habitat and native species to the Waiapu, matauranga Ngāti Porou is commonly utilised across the community, as it connects to hunting, gathering, cultivations, preparation, storage and consumption of food.
	xi.	Karakia are revived through the identification and protection of natural springs.
	xii.	Maara kai are re-established in the Waiapu reconnecting whanau and the concept of manaakitanga.
	xiii.	Gathering practices from native forests for food are revived and part of the staple diet of Ngāti Porou.
	xiv.	Tikanga associated with kapata kai commonly understood and practised in Ngāti Porou.
	xv.	Taniwha are identified and revered as kaitieki.

[1] (Pohatu pers comm. 2011)
[2] (Kaa pers comm. 2011)

Cultural Inventories *"This is nature telling us to do something positive. We are finding birds where they never were before. Nature is telling us to change and we are not listening very well. Or we are listening but we are helpless to do anything. It has to start in the whole catchment, not just in this area, where the Waiapu starts"[1].*	xvi.	Cultural inventory of freshwater environs of the Waiapu complete and monitored.
	xvii.	Kapata kai areas are clearly identified and managed by Ngāti Porou through traditional methods including rahui.
	xviii.	Cultural inventory of vegetation species found in the Waiapu catchment complete and monitored.
	xix.	Cultural inventory of plants for raranga species found in the Waiapu catchment complete and monitored.
	xx.	Cultural inventory of fauna species found in the Waiapu catchment complete and monitored.
	xxi.	Cultural health indicators are in place in the Waiapu based on an oral history project that recorded past uses and relationships between Ngāti Porou and the Waiapu.
Waahi Tapu *"That maunga Pohautea, there is a moteatea, Ngatorou and it's based on Pohautea, Hikurangi is tapu but so is Pohautea.* *We call it the guardian of the river and at the rate of erosion as it has been in the last few years Pohautea will be gone[2]."*	xxii.	Traditional names of Waahi Tipuna commonly known and sign posted.
	xxiii.	Waahi tapu inventory completed.
	xxiv.	Waahi tapu are not at risk from being negatively impacted by erosion.
	xxv.	Areas of land are reserved for wananga and other traditional practices.
Ngāti Porou Marae *"We must come together as landowners on each side of the river and come to agreements. We need to see how the river goes to the sea. I don't think the river likes straight lines. And we come to an agreement we all go and fish for a cockabully and eels and go along that line that we think is the right way for the river to go. We'll cook our lunch up and go and leave the rest to the river[3]."*	xxvi.	Ngāti Porou Marae are welcoming, safe, vibrant and evolving sites to practice and 'be' Ngāti Porou.
	xxvii.	Ngāti Porou Marae and hapu are the vehicles for sustainable development.
Whakapapa *"Whakapapa perpetuates Whanungatanga[4]."*	xxviii.	Whakapapa research teams are established to assist Ngāti Porou to record and access their whakapapa and strengthen their relationships with each other and our natural environment.

[1] (Maro pers comm. 2011)
[2] (Atkins pers comm. 2011)
[3] (Maro pers comm. 2011)
[4] (Harmsworth et al., 2002)

Criterion 4: Ngāti Porou - Mana Motuhake

"We want to own our river. He pai ta tatou kōrero, Ko Hikurangi te Maunga, a ka hoki mai te Waiapu te awa. It doesn't belong to us at the moment"[1].

DESIRED STATE: "EHARA TAKU MAUNGA A HIKURANGI I TE MAUNGA NEKENEKE, HE MAUNGA TU TONU. KO TOKU KINGITANGA MAI I AKU TIPUNA I TE IHU TO MAI I TE PO" (TE KANI A TAKIRAU)

		Indicator
"We need full ownership and authority over our river, every other person has a stake in our river. It is hard for us to plan around everyone else's agenda on the river. How can we in law take back ownership if you can call it that? I know our people don't look at it like that. Like Tuwharetoa owning the beds of the lake. We need to make the decisions over our waters[2]".	i.	Ngāti Porou hapu own the bed of the Waiapu and the air column above it.
"There are things that can strengthen our argument like contiguous ownership[3]".	*ii.*	Ngāti Porou hapu are making decisions over erosion management policies and programmes for the Waiapu.
	iii.	Ngāti Porou are the consenting authority over the Waiapu through a section 33 transferral of powers in the RMA 1991
	iv.	Ngāti Porou have effectively created and implemented successful erosion policies that are driven by the people on land that they directly control.
	v.	Ngāti Porou hapu have co-management and co-governance arrangements with the Gisborne District Council that share planning responsibilities similar to those of the Waikato River Settlement.
	vi.	Ngāti Porou hapu have a clear strategy to the management and protection of the Waiapu and is implementing this as an Iwi Management Plan under the RMA and other agreements.
	vii.	Ngāti Porou are engaged with central government to ensure that national policies do not increase the degradation of the Waiapu.

[1] (Tangere pers comm. 2011)
[2] (Warmenhoven pers comm. 2011)
[3] (Warmenhoven pers comm. 2011)

Criterion 5: Ngāti Porou - Economic Indicators

They brought cows in from Taranaki, and our side of the river the land was sectioned into little blocks and it was a busy place. From the cows we would send our cream to the factory. We even had our own school, the Waiapu Primary, and everybody was important to one another and they had things within their grasp because with cows and pigs and chooks we had everything. All that was around the river. We want all of this back. Because now the river has taken part of the land, maybe we are not listening to it[1].

DESIRED STATE: "OUR LAND NEEDS OUR PEOPLE. IT NEEDS OUR ENERGY. IT NEEDS THE YOUNG: IT NEEDS YOUR ENERGY"

Category		Indicator
Technology *"LIDAR mapping could be an answer for us. They are taking tonnes out of the river, but they might be taking it out at the wrong place. We could use it to improve the river*[2]*".*	ii.	Ngāti Porou have developed IT opportunities and products in communications, erosion control and land management tools.
	iii.	Ngāti Porou have identified and are establishing alternative routes and transport options along the East Coast to improve roading options that will not be effected by erosion prone areas.
	iv.	Ngāti Porou understand the alternative port options for transporting goods overseas.
Business *"Maybe our people can get work planting native forests again. Then the native birds can go back into the forest where they belong without coming into town looking for food... our people are down on their knees, they are struggling. We need to go back to crops and natives to employ our people."*[3].	v.	Tourism Ngāti Porou is a thriving business that is working on the Waiapu.
	vi.	Afforestation is a core business of Ngāti Porou with a range of species for wood, food and medicinal purposes being utilised.
	vii.	Maara kai have grown to create opportunities for organic food export with Ngāti Porou branding.
	viii.	Ngāti Porou businesses progress sustainable development without environmental degradation to exercise kaitiekitanga and to reduce RMA compliance costs.
	ix.	Ngāti Porou businesses operate under the Waiapu Environmental Strategy policies and are committed to its implementation.
	x.	Ngāti Porou business are thriving in the Waiapu and employing Ngāti Porou as the largest collective employer in the district.
Investment *"Give the problems of the Waiapu back to the*	xi.	Ngāti Porou are actively investing in erosion prevention and remedial action collectively on an annual basis to an agreed strategy.

[1] (Maro pers comm. 2011)
[2] (Maro pers comm. 2011)
[3] (Maro pers comm. 2011)

government. They are the ones who buggered it up. They are the ones who encouraged farming and the cutting down of the native trees, those Pakeha farmers. (All those Pakeha farmers have sold up and shipped out.) Let them fix them it up. Our mokopuna should get it back when it is fixed. The mana of Ngāti Porou will always be the awa tapu, they cannot take that away from us[1]."	xii.	Afforestation schemes are expanded and paid in advance to enable more Ngāti Porou to uptake the programmes.
Land *"The life of the river is just about gone. That is to do with the way we have managed the land and the water"[2].*	xiii.	Ngāti Porou understands the land use capability and land use currently of whenua in the Waiapu and develops according to Ngāti Porou tikanga.
	xiv.	Land use management tools are in place and influence erosion control policies in the Waiapu.

[1] (Maro pers comm. 2011)
[2] (Maro pers comm. 2011)

Appendix 10: Average ECFP grant rates & uptake in the Waiapu catchment – derived from last 3 application rounds

Source: Hambling R., pers comm. (2012) – MAF

Forestry treatment – 70% grant paid out 1st year, 30% around year 8

General title 1651ha at average grant of $2072/ha

Maori land 966ha at average grant of $2005/ha

Indigenous Reversion – 50% grant paid out 1st year, 50% at year 5

General 288ha at average grant of $1630/ha

Maori land Nil

Pole planting – 80% grant paid out 1st year, 20% at year 3. Note that this treatment is used on less eroding land.

General 652ha at average grant of $597/ha

Maori land Nil

Note on remaining untreated target land within the catchment

MAF has previously approved around 35% of the remaining untreated target land (i.e. 4,416 ha). Of this, 3,216 ha have lapsed due to not being treated in the year of approval. The main reasons effecting 70% of this area were an Overseas Investment Office decision, a substantial landowner changing their mind/reducing their programme, and the lack of joint-venture partner (before carbon investors arrived) (R. Hambling, pers. comm.).

Appendix 11: Areas of land use classes by land tenure for 1969, 1990, & 2008

Areas of land use classes within Crown Land for 1969, 1990, & 2008.

1969 Land Use	Area (ha)	1990 Land Use	Area (ha)	2008 Land Use	Area (ha)
Exotic Forest 1969-1975	-	Cropland	0.1	Cropland	0.1
Grassland / Cropland	6136	Grassland	1600	Grassland	626
Scrub	435	Grassland with Woody Biomass	293	Grassland with Woody Biomass	301
Native Forest	979	Natural Forest	1487	Natural Forest	1470
Undefined Forest	287	Planted Forest pre-1990	14574	Planted Forest pre-1990	14553
N/A	-	N/A	-	Post 1989 Planted Forest	1020
Undefined Other	170	Other	201	Other	186

Areas of land use classes within General Title for 1969, 1990, & 2008.

1969 Land Use	Area (ha)	1990 Land Use	Area (ha)	2008 Land Use	Area (ha)
Exotic Forest 1969-1975	4816	Cropland	153	Cropland	150
Grassland / Cropland	56359	Grassland	54685	Grassland	39771
Scrub	4658	Grassland with Woody Biomass	3759	Grassland with Woody Biomass	3155
Native Forest	8560	Natural Forest	11790	Natural Forest	11212
Undefined Forest	826	Planted Forest pre-1990	4660	Planted Forest pre-1990	4635
N/A	-	N/A	-	Post 1989 Planted Forest	16495
Undefined Other	2727	Other	2879	Other	2504

Areas of land use classes within Māori Title for 1969, 1990, & 2008.

1969 Land Use	Area (ha)	1990 Land Use	Area (ha)	2008 Land Use	Area (ha)
Exotic Forest 1969-1975	1394	Cropland	216	Cropland	216
Grassland / Cropland	25460	Grassland	24146	Grassland	19954
Scrub	6987	Grassland with Woody Biomass	2370	Grassland with Woody Biomass	1715
Native Forest	18761	Natural Forest	25228	Natural Forest	24639
Undefined Forest	885	Planted Forest pre-1990	1217	Planted Forest pre-1990	1217
N/A	-	N/A	-	Post 1989 Planted Forest	5718
Undefined Other	752	Other	1062	Other	779

Areas of land use classes within Doc Land for 1969, 1990, & 2008.

1969 Land Use	Area (ha)	1990 Land Use	Area (ha)	2008 Land Use	Area (ha)
Exotic Forest 1969-1975	45	Cropland	-	Cropland	-
Grassland / Cropland	181	Grassland	280	Grassland	274
Scrub	152	Grassland with Woody Biomass	303	Grassland with Woody Biomass	312
Native Forest	22313	Natural Forest	22787	Natural Forest	22787
Undefined Forest	787	Planted Forest pre-1990	42	Planted Forest pre-1990	42
N/A	-	N/A	-	Post 1989 Planted Forest	54
Undefined Other	28	Other	87	Other	31

Annex

Research gaps & recommendations for future work

Social, cultural, & economic aspects

Based on the review of relevant literature and the feedback from the consultation undertaken as part of this study, the following were identified as knowledge gaps and areas for future research. These are listed in order of priority:

1. There is no integrated and overarching strategic plan for the catchment that describes how the aspirations of Ngāti Porou, as described in this report, maybe achieved. The development of a plan that describes plausible scenarios for the future co-developed by all stakeholders will aid the community and decision makers in their deliberations on likely options and choices. Any strategic plan should be supported by the development of a co-governance body that includes all relevant agencies and community representatives. Further research is required on the best and most appropriate co-governance model appropriate to the needs of the catchment and the community.
2. An evaluation of the impact of erosion and land degradation on the livelihoods of Ngāti Porou should be undertaken. The Waiapu community may be viewed as possessing financial capital, social capital, human capital, physical capital, and environmental capital. Erosion and subsequent land degradation has reduced these capitals in many direct and indirect ways and thereby reduced the ability of the community to sustain itself. A better understanding of the impacts of erosion on local people will help inform the development of policy and guide the community's own responses to the challenges they face in a more targeted and effective way. To be a resilient community able to withstand future natural, political, or financial shocks, the level of all of these forms of capital must be raised. To be in a position to take the necessary long-term view when planning land usage — this similarly requires a solid and resilient base. People living week to week cannot be expected to overlook pressing need and make investments with a return 20-100 years away. An aspirational set of measurables based on these forms of capital is essential not only as a source of specific developmental targets, but also as a way to gauge progress both internally and in relation to the country as a whole. To repopulate and thrive, the catchment has to not only recover, but has also to compete favourably as a place to locate a family when weighed against alternatives such as Gisborne or Wellington.
3. Land use optimisation and local community economic development should be investigated. Using the livelihoods approach described above, a series of land use

options should be developed and supported by a detailed understanding of the capital held within the community. This understanding will help to guide an evaluation of the likely success of each option and highlight obstacles to implementation such as training needs and lack of access to financial capital.

4. Quantification of the ecosystem and environmental services provided by the Waiapu and its tributaries to Ngāti Porou including kapata kai should be undertaken. Using non-market valuation techniques to survey local people together with econometric analysis, the social and cultural values of the ecosystem services to the local people in the catchment may be estimated. In addition, the reduced ecosystem function associated with erosion could also be quantified, for example, the loss of kapata kai, fish, and plant resources. The result would be an estimation of the economic impact of erosion on a community and region.
5. An evaluation of the impacts of erosion on archaeological and wahi tapu sites within the catchment needs to be addressed. Important sites should be identified and safeguarded from further damage and loss. Consideration should be given to the restoration of damaged sites and active management plans put in place.
6. The Ngāti Porou aspirations and supporting indicators require further consultation and refinement with the wider community. Indicator processes are not static and require iteration and development over time as priorities emerge and the desires of the community are better articulated.
7. Effective community engagement processes towards improving the health of Waiapu catchment and in erosion and catchment management through greater scientific awareness and improved technology transfer between interested parties, including CRI's, GDC, Ngāti Porou, and other landowners are required.

Geophysical & land use aspects

Based on the review of relevant literature and consultation with researchers who have worked in the Waiapu catchment, the following were identified as knowledge gaps and areas for future research. These are listed in order of priority:

1. The rates of erosion and relative sediment contribution by processes other than gully erosion under different land uses and land management practices have not been sufficiently quantified. Research should be undertaken to achieve this. These other processes account for 51% of the sediment yield.
2. The impact of reduced hillslope sediment supply on river sediment transport. Specifically, how much afforestation, reversion, and wide-spaced tree planting is required, and what is the interval or lag time, to affect a switch from aggradation to incision, and what is the rate at which it will propagate from headwater streams to the

main stem of the Waiapu River are unanswered questions. This rate may also be influenced by the volume of sediment stored in the Waiapu River network, which is also unknown. The absence of cross-sections in many tributary streams and the irregularity of cross-section surveys currently limit the ability to address this issue. A network of adequately spaced and regularly surveyed cross-sections is essential to better understand the dynamics of bedload transport and to link patterns and rates of aggradation and incision to land use changes.

3. The impact of increased sediment supply to the river channels on the availability and quality of freshwater habitats for indigenous and introduced fish species (e.g. suitable sites for spawning, incubation of eggs, and rearing of young) is largely unknown. Data on benthic invertebrates are lacking. The co-benefits likely to accrue from land use change (revegetation) on stream habitat and the hydrological regime have yet to be adequately quantified. Appropriate research and monitoring should be undertaken to address these knowledge gaps.
4. The role and influence of riparian zones on stream health and for stream restoration is currently not sufficiently well understood. Further research on this is required.
5. Implementation of a monitoring strategy is necessary to identify sedimentation patterns and associated changes in marine fauna. Sufficient information is not currently available.
6. The effect of declining sediment supply and future storm events on channel morphology (width and shape) is currently not well understood. Changes in channel morphology will have an effect on future flooding, sedimentation, bank erosion, infrastructure (bridges) and instream habitat values. Further research is required to address this issue.
7. The impact of future aggradation/incision rates in different reaches and tributaries on infrastructure such as bridges and roads is currently not well understood. The majority of existing cross-sections are located in the two worst eroding catchments and reflect GDC‘s concern of damage to several bridges. Loss of access affects economic viability, social cohesion and is an ongoing cost. Establishment of additional cross-sections is needed.
8. The relative effectiveness of vegetation in controlling the different types of erosion has been better quantified for exotic forestry, principally *Pinus radiata*, and indigenous reversion than for wide-spaced tree planting and other exotic species. A greater research effort is required to quantify the effectiveness of wide-spaced tree planting (including willows, poplars, and indigenous species), particularly their optimal spacing, root reinforcement properties, and management requirements, over a range of event magnitudes and for the different erosion types.

9. Further research into the effectiveness of indigenous reversion as a means of erosion control is required.
10. The impacts (and uncertainties) of forecast climate change (rainfall and storm magnitude/frequency) on hill slope erosion, and river behaviour and sediment transfer are currently not well understood or quantified. Increase in storm rainfall will cause erosion and sediment yield to increase. Further research is required to address this issue.
11. The relative contribution of sediment yield to bedload and suspended load from different land uses and land systems, and how this might be affected by land use change and/or gravel extraction has not been adequately quantified. Further work to address this is required.
12. Little analysis has been performed on existing rainfall, river flow, and suspended sediment data. A detailed analysis and review of this data would be useful to establish whether more data is required, the usefulness of the data currently being collected, and what new data (if any) might be more useful.
13. The impact of a large magnitude earthquake on hill slope erosion, and river behaviour and sediment transfer is not well understood. Further research is required. However, this can only be assessed after an event.
14. Knowledge of the properties and distribution of soils in the hill and high country areas of Waiapu catchment is currently limited. While soils of the floodplain and low lying areas have been mapped in sufficient detail this needs to be extended to the rest of the catchment. This is important for improved land use sustainability and productivity.