



## Chapter 10

# Summary of Findings

*Garth Eyles and Barry Fahey*

### Historical slip erosion:

- In 1943, slip erosion scars covered 9.4 ha or 1.2% of the Tamingimangi catchment (total area 795 ha), and 10.6 ha or 1.4% of the Pakuratahi catchment (744 ha).
- In 1970, the area in slip erosion was only 0.06% of the Tamingimangi catchment, and 0.01% of the Pakuratahi catchment.
- After Cyclone Bola in 1988, the area in slips increased to 7.3 ha (0.91%) in the Tamingimangi catchment, and 1.1 ha (0.14% in the Pakuratahi catchment).
- By 1994, coinciding with the commencement of the study, the area in slips in the Tamingimangi catchment had declined to 2.7 ha (0.34%) and to 0.2 ha (0.02%) in the Pakuratahi.
- At the end of 2005, corresponding with the completion of the study, slip erosion scars covered only 0.23 ha (0.03%) of the Tamingimangi catchment, and 0.14 ha (0.04%) of the Pakuratahi catchment.
- In the absence of any extreme events during the course of the study, the area covered by slip erosion has fallen in the Tamingimangi catchment, and remained static in the Pakuratahi catchment.

### Pastoral Farming

- Livestock grazing is the farming activity on the three properties in Tamingimangi catchment, comprising a mix of store sheep and cattle, and a stocking rate of 10–12 su/ha.

### Forest management

#### *Pre-harvest phase*

- The Pakuratahi catchment was planted during the period 1970-1972 from pasture and subsequently pruned and thinned-to-waste and production thinned to a final stocking density of 225 stems/ha.
- The 8.2 km of access road provided a road density of 0.2 km/km<sup>2</sup>

#### *Harvest phase*

##### Planning

- Harvest planning was typical of that for any steep sensitive forested area in the Pan Pac estate in coastal Hawke's Bay hill country.
- Because of the numerous ridges, gullies, and side spurs in the Pakuratahi catchment, road and landing density was high.
- Most of the forest (85%) was cable logged using a BE70 and BE85 yarder, except for the ridge crests which were harvested using a tractor and a rubber-tyred skidder.



- To minimise soil disturbance, extracted trees were stacked on small landings and trucked to a large centralised landing for processing, enabling the former to be kept to a minimum size to reduce earthworks.

#### **Roads and landings**

- Where practicable roads and landings were kept to ridge tops.
- The 8.2 km of existing roads were up-graded, and 3.7 km of new road constructed, with a subsequent road density of 0.35 km/km<sup>2</sup>.
- A total of 52 hauler pads (small landings covering approximately 0.06 ha) were used during harvesting, of which 25 were new, 20 were up-graded, and 7 needed no additional earthworks. The two larger log processing sites were outside the catchment.

#### **Harvesting**

- Harvesting commenced in December 1997, with approximately half the forest (152 ha) removed by January 1999, and the total removed (312 ha) by the following October.
- Although environmental impacts were minimised, safety standards, value maximisation, and production were not compromised.

#### **Post harvest Phase**

- Between 1998 and 2000 the harvested area was aerially desiccated to reduce weeds, over sown, and pests such as feral goats eliminated.
- Replanting in radiata pine took place at 830 to 850 stems/ha between 1998 and 2000.
- Pruning to approximately 300 stems/ha in some areas occurred through 2002 and 2003, with canopy closure being achieved in 2005.
- The area currently in forest is about the same as that before harvesting.

## **Forestry effects on stream flow and water yield**

#### **Annual water yields**

- In the pre-harvest period (1995–1997), annual water yields from the Pakuratahi were 25 mm (6%) per year lower than those from the Tamingimangi.
- Harvesting and the associated loss of the forest canopy between 1998 and 1999, caused annual water yields from the Pakuratahi to exceed those from the Tamingimangi by an average of 71 mm (22%).
- Despite the growth of the new crop, the higher annual water yields from the Pakuratahi catchment have persisted through the post-harvest period (2000–2005), averaging 61 mm (16%) above those from the Tamingimangi.
- In 2005 the difference in annual water yields declined to 5%, suggesting that forest canopy closure is finally having an effect on streamflow, but it is likely to be some years before water yields return to pre-harvest levels.
- A comparison of the proportion of rainfall flowing from the catchments shows a similar pattern to that of water yields. Since 1998 the Pakuratahi has consistently produced a higher propor-



tion of rainfall as flow than has the Tamingimingi. The difference between the 2 catchments may be closing but there is too much variability to be confident that this will occur soon.

#### **Annual quickflow**

- Annual quickflows (representing the rapid response of streamflow to rainfall) vary in accordance with variations in rainfall. Apart from 1995, 1996, and 2002, those from the Pakuratahi exceeded those from the Tamingimingi on a unit area basis.

#### **Annual delayed flow**

- Annual delayed flows (representing total baseflow from soil and groundwater storage) from the two catchments show the same patterns and trends as seen in the annual water yields. Those from the Pakuratahi were 8% above those from the Tamingimingi before harvesting, but rose to 22% above between 1998 and 2002, declining each year since then to 6% in 2005.

#### **Low flows**

- Minimum annual 7-day low flows were consistently higher from the Pakuratahi catchment compared to the Tamingimingi through the pre-harvest period. This is the reverse of what might be expected from a forested catchment, and is believed to reflect greater groundwater seepage that is able to sustain higher baseflows in the Pakuratahi compared to the Tamingimingi. The difference increases after harvesting, but by 2004 they were approaching pre-harvesting levels, suggesting that at least 5 years will elapse before low flows return to pre-harvesting levels.

#### **Storm flows**

- Peak storm runoff was greater from the Tamingimingi during the pre-harvesting phase and also during the post-harvesting phase. Pakuratahi peak flows exceeded those from the Tamingimingi during harvesting, but more especially from 1999 when about 40% of the crop had been removed. By mid-July 2000, storm peak flows from the Tamingimingi began to dominate again 6 months after logging had ceased. Peak flows have remained between 15 and 65% lower from the Pakuratahi than from the Tamingimingi.

## **Forestry effects on sediment yield and erosion**

- The pasture catchment yielded 3–4 times more suspended sediment than the mature plantation forest catchment before harvesting.
- During the logging phase of the harvesting period, sediment yields increased 2–3 times above those from the pastured catchment.
- The combination of a reduction in forest-related activities after harvesting, coupled with over sowing and rapid replanting reduced sediment yields to those comparable to pre-harvest levels within 2–3 years.
- Total suspended sediment yield from the forested catchment over the 11-year period of record was substantially less than that from the pasture catchment.
- An erosion risk model showed that 24% of the Pakuratahi catchment and 21% of the Tamingimingi catchment comprise areas regarded to be of moderate to high erosion risk; only 2% of the Tamingimingi and 6% of the Pakuratahi was identified as being very high risk areas.
- Slopewash on cutovers is not an important sediment generating process; in this study it yielded only 1% of the total suspended sediment load from the Pakuratahi catchment.



- The main sources of sediment are cutbank and sidecast failures, shallow landslides, and channel beds and banks.
- Bedload was a very minor component of the total load.
- Sites of deep-disturbance, associated with hauler-logging, occupied just 9% of the logged setting, which is at the low end of the range of values found for similarly logged settings elsewhere in New Zealand.
- After harvesting, groundcover vegetation was effectively reduced to zero on sites of deep-disturbance, and to <10% on sites of shallow-disturbance.
- Recovery was fastest on the less disturbed sites; vegetation occupied about 80% of both site disturbance classes within 6 months.
- Within 2 years of the completion of logging and subsequent aerial desiccation, followed by over sowing, vegetation occupied 80% of deep-disturbance sites, and 97% of shallow-disturbance sites.

### Forestry effects on Water quality

- Streams draining pasture and areas in mature forest have similar levels of turbidity, nitrate-N, total P, and total dissolved P.
- Harvesting did not cause any statistically significant increase in the concentrations of any of these parameters.
- Electrical conductivity and pH levels showed small increases after logging, although that for pH could not be entirely attributed to harvesting effects.

### Forestry effects on Channel morphology and channel vegetation

- In the pre-harvest period mature forest cover in the Pakuratahi was more effective at moderating storm impacts on channel morphology than pasture land in the Tamingimingi.
- Harvesting raised stream bed levels in the Pakuratahi, particularly in the headwater sites, in response to increased sedimentation and wood debris.
- In the immediate post-harvest period, a storm event in January 2000 had a greater impact on channel morphology in the Pakuratahi compared to the Tamingimingi, mobilizing in-channel sediment and logging slash.
- Increased light levels following harvest have stimulated rapid establishment of vegetation in the stream channels at all three sites.
- The combination of woody debris and vegetation is trapping and retaining sediment in the headwater streams, which may be contributing to the reduction in sediment yields and peak storm flows in the early establishment phase of the forest rotation.
- In the Pakuratahi streams the gradual die back of channel and bank vegetation as shade levels increase, and decomposition of logging slash, may eventually cause the mobilization of previously retained sediment especially during flood events.



- Channel conditions in the upper reaches of the Pakuratahi catchment have undergone marked changes during the harvest and post-harvest phase, and it is likely that further channel changes will occur as shade levels increase. In comparison channel morphology has remained relatively stable in the Tamingimingi.

### Forestry effects on stream invertebrate communities

- Immediately after logging, stream invertebrate communities changed from being dominated by mayflies to more impact-tolerant taxa such as midge larvae, beetle larvae and snails. Similar communities were recorded in streams draining pasture sites in the Tamingimingi catchment.
- The smaller streams in the Pakuratahi catchment were most affected by logging, and took at least 5-6 years for their biological characteristics to return to their pre-logging condition. This is probably a result of the build-up of silt in these small streams.
- The site above the weir, which is deeper and faster flowing, exhibited lower levels of sand and silt, and the fauna recovered more rapidly.
- Effects of logging operations on stream invertebrates can be minimized by reducing sediment inputs to the stream bed, especially in the smaller headwater streams which do not have sufficient flow to remove the sediment.
- Recovery is likely to take at least 6 years in small headwater streams, but may be faster in larger sub-catchments.

### Forestry effects on native fish communities

- The Tamingimingi catchment has had minimal change in habitat and species variability because of the comparatively stable pastoral management regime. The Pakuratahi in contrast has had a change in stream bank cover, resulting in migration of fish to other reaches.
- This results in variation of fish numbers based on the reach type with the riffles and runs being most productive and the pools being least productive.
- Fish numbers are similar in both catchments, ranging from 0.5–6.8 /m<sup>2</sup> for the Pakuratahi, and 0.5–3.2 /m<sup>2</sup> for the Tamingimingi over the course of the study.
- Fish numbers, and thus biodiversity, have varied in both catchments over the past 10 years in response to land use and minor impacts from storms.
- The fact that both catchments are spring fed has meant that land impacts are buffered.
- The results suggest that forest harvesting has not had a particularly negative impact, and that any effects are offset by the enhanced riparian vegetation creating larger stream habitat for certain species.

