Research and monitoring advice on environmental impacts of forestry in the Gisborne-East Coast Region

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Landcare Research

Prepared for:

Gisborne District Council

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Summary

Project and Client

- Gisborne District Council (GDC) approached Landcare Research to provide input and advice to develop a 'research and investigation programme' to meet a range of council, community, central Government and forestry needs.

Objectives

- Design and lead a workshop with GDC staff and stakeholders to begin to co-develop investigations/research related to the management of risk of landslides, debris flows and slash mobilisation.
- Scope a research programme on how to better manage the environmental effects of forestry, and identify where this land use may be considered unsustainable due to the risk of landsliding and debris flows.
- Contribute to a report and recommendations to Council by February 2016.

Methods

- In collaboration with GDC, design and lead a 1-day workshop in Gisborne with GDC staff and their forestry stakeholders.
- Prepare and collate background information in the form of PowerPoint presentations, summary notes, and other material deemed useful for the discussion.
- Collate and summarise notes from the workshop and prepare a short report outlining what was discussed and recommendations for addressing the need.

Results

- A workshop in two parts explored the issues facing GDC in respect of landslide-debris flow-slash mobilisation events and their management, and a wider perspective on forestry land use and its longer-term effects on the environment.
- Suggested approaches were discussed, and options received general support and form the basis of the recommendations in this report. These are essentially next steps prior to more formal development of a research and monitoring strategy.

Conclusions

- Managing debris flows and other post-harvest impacts is not an easy task and they will continue to occur in the future.
- The challenge is to <u>manage for</u> their occurrence, adopt any measures that could <u>reduce</u> their number, and <u>reduce</u> the impacts they have on downstream environments.

- Management of post-harvest impacts requires a better understanding by all stakeholders (including the public) about the nature of the processes, their occurrence and under what conditions these phenomena happen.
- There was wide acceptance amongst workshop attendees of the need to develop some form of risk matrix that would help with decision-making, and to collect useful and credible information on debris flow occurrences, their impacts and what drives them.
- GDC has an issue managing the expectations of its community, many of whom have voiced considerable displeasure at the on- and off-site effects of forestry. Obtaining relevant, credible and defensible information to inform the public is thus a high priority need.

Recommendations

- Six key groups of recommendations are made. These include information gathering and review, developing a risk management matrix for Gisborne region, environmental monitoring, land zoning for future forestry, education and advocacy, and funding and support.
- Recommendations that received universal support included a stocktake of current information; development of a template for post-event information gathering and criteria to be collected; development of a risk management matrix with associated categories and criteria; collaboratively determining criteria for identifying parts of the landscape where plantation forestry could/should be restricted due to the potential risk of landslides and debris flows.
- Solicit the interest of other councils in pursuing a joint Envirolink Tools project to develop a national risk matrix or similar tools (event templates, etc.) that can provide information to meet a broader national need but are adaptable to local conditions.

1 Introduction

Gisborne District Council (GDC) approached Landcare Research to provide input and advice to develop a ‘research and investigation programme’ to meet a range of Council, community, central government and forestry needs. This need has arisen due to increasing community pressure on Council to respond to the effects of storm-induced, post-harvest landslide and debris flow activity that have in recent events mobilised large amounts of woody debris ultimately depositing this on local beaches or properties adjacent to plantation forests. In addition, the council as part of its statutory responsibilities is required to report on the environmental effects of land use activities and plantation forestry is under-represented in GDC’s environmental sampling network.

2 Background

Plantation forestry is a significant land use in the Gisborne-East Coast Region, providing a number of benefits including soil conservation, employment, and economic value. However, there are a number of issues associated with forestry, particularly during and post-harvest, that impact on both the environment and the communities of the region. Amongst these is the issue of storm-induced, post-harvest landsliding and debris flows, which mobilise slash (harvesting residue) on slopes and in channels and deliver it to neighbouring properties, river flood plains, and to the coast, where it ends up on beaches. It also poses a risk to infrastructure such as culverts, bridges, roads, and rail. A number of incidents within the last 5 years have raised the ire of coastal communities, iwi, and the farming community and have resulted in many letters to the local paper and pressure on GDC to ‘tackle the issue’.

For example, a recent event in September 2015 in Gisborne District caused $500k damage to bridges, culverts and roads, as well as substantial deposition of wood and sediment on farmland. These direct costs, while significant, may pale by comparison if the loss of productive capacity of the land due to soil loss could be estimated in monetary terms. In many cases these events have an Annual Recurrence Interval (ARI) around 1:10 to 1:25 years (see Appendix 3, Point 5 for further discussion).

It should be noted that this is not an issue unique to this region, but is one that occurs in many other parts of New Zealand, where it also receives attention from councils, communities and forestry companies. Recent and legacy articles, reports, and Environment Court evidence suggest that this phenomenon is not new and will continue in the future wherever forests are harvested from steep, erosion-prone land subject to large rain storms (e.g. Payn et al. 2015; Basher et al. 2015; Phillips et al. 2015; Marden et al. 2015; Phillips et al. 2012). The North Island and the top of the South Island appear more vulnerable to rainstorm events that trigger landslides, slash mobilisation and debris flows.

The nature of the issue and what science has been done to address it and more general observations have been described in the papers cited above and are summarised in Appendix 3.

3 Objectives

- Attend and lead a workshop with GDC staff and stakeholders in December 2015 to begin to co-develop investigations/research related to the management of landslide, debris flow and slash mobilisation risk.
- Scope a research programme or case studies into how to better manage the environmental effects of forestry, and identify where this land use may be considered unsustainable due to the risk of landsliding and debris flows.
- Discuss and identify changes needed to the way slash and riparian buffers are managed.
- Discuss and identify how the council and industry could implement a more formal risk management analysis approach to these issues and how case studies might be used to test a different approach.
- Contribute to a report and recommendations to Council by February 2016.

4 Methods

- In collaboration with Lois Easton (GDC) a 1-day workshop in Gisborne with GDC staff and their forestry stakeholders was designed and undertaken (Appendices 1 and 2).
- Background information was prepared in the form of PowerPoint presentations, summary notes, and other material deemed useful for the discussion.
- Notes from the discussions at the workshop were collated and summarised and a report prepared outlining what was discussed and recommendations for addressing the GDC needs.

5 Results

5.1 Background information

Background information was pre-circulated or tabled at the workshop, some of which is included in Appendices 3 and 4.

- PowerPoint presentation ‘Landslide and debris flow prediction and risk analysis’ that included an example of a risk management matrix developed by Nelson Forests and an example of a terrain assessment developed by Hancock Forests
- Notes presented at November 2015 ‘Steepland forestry workshop’ held in Gisborne
- A report prepared for Scion as part of the MBIE GCFF programme – ‘Tools for assessing on-site and off-site risks of landsliding in steepland plantation forests’ (Basher 2015) (not included in this report but available on request).

5.2 Workshop Part 1

The day-long workshop was split in two parts. The morning session (Part 1) with invited forestry stakeholders (Appendix 2) began with a short scene-setting summary by Chris Phillips of the notes on debris flows and landslides he gave at the 2015 November steeplands workshop in Gisborne (Appendix 3).

Les Basher then gave a summary of what is meant by susceptibility, hazard and risk; discussed New Zealand and overseas work on predicting landslide and debris flow hazard; and discussed two different approaches used by forestry companies in New Zealand (a risk management matrix used by Nelson Forests and a terrain stability approach used by Hancock Forest Management) (Appendix 4).

Marty Watson (PF Olsen) outlined the activities of the East Coast Forestry Forum (a subgroup of the Eastland Wood Council with representatives from the major forest companies and Council staff). They have spent a lot of time discussing debris flows and slash mobilisation with a focus on practical solutions (what’s working well, what’s not working). They have also submitted on the proposed National Environmental Standard (NES) for Plantation Forestry and the GDC Freshwater Plan. They have a database of debris flow occurrence in the district and an assessment of mitigation performance, specific details of which were not outlined.

Trevor Freeman (GDC) spoke briefly about how the Resource Management Act defines the duty to avoid, remedy, or mitigate adverse effects on the environment (section 17), the meaning of effects (section 3) that includes a potential effect of low probability which has a high potential impact, and how section 341 provides for recognition of events beyond the control of a land manager (“acts of God”). There is case law on all three provisions.

Discussion then turned to risk management, with general agreement that a risk management matrix (e.g. Figure 1) (similar to the Nelson Forests example in Appendix 4) might provide a transparent and documented mechanism to better identify and manage post-harvest risks from landslides, debris flows and slash mobilisation in the Gisborne region.

A risk matrix is a common way to assess the relationship between a hazard, the probability it will occur and the magnitude of its impact in physical, social and economic terms (i.e. risk). They are widely used to objectively and transparently assess risk, assist management decision-making and meet community expectations. A risk matrix typically comprises a measure of severity (the physical, social and economic effects) and a measure of the likelihood of a triggering event. Measures of severity would consider the extent of exposure of the different receptors identified (e.g. people, infrastructure, stream habitat, etc.). Likelihood of the impact occurring would be something like the probability of a storm occurrence (annual exceedance probability, AEP) coinciding with a recently harvested area. While commonly used, they are not without their problems (e.g. Cox 2008), most of which are associated with categorization and quantification of thresholds between classes.

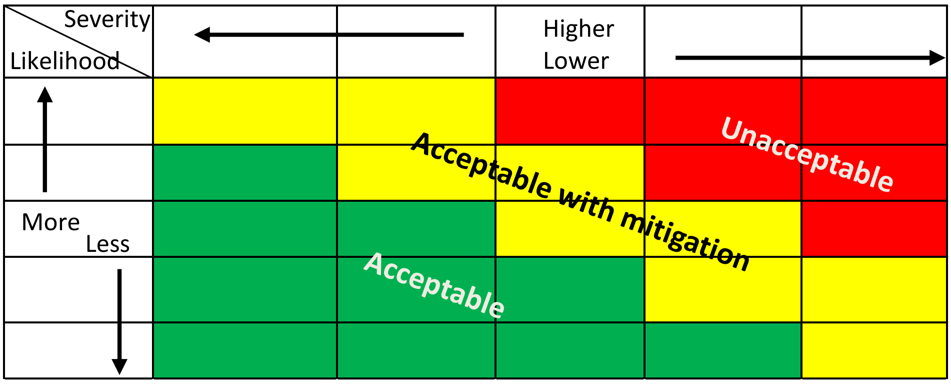

Figure 1 An example of a generic risk matrix

Criteria (categorization and boundary thresholds) would need to be developed that were suitable for use in the Gisborne region. The risk matrix would need to consider downstream effects resulting from failure of any one of multiple source sites. Detailed mapping might also be needed to effectively implement a risk management matrix operationally. There was discussion on a more generic national approach, such as proposed in the earlier version of the NES for plantation forestry, which could be 'tweaked' for any local conditions. There was also discussion regarding the need to develop criteria for identifying areas that might not be replanted due to unacceptably high risk following harvesting, based on factors such as poor tree growth, difficulty of harvest, and higher risk for generating debris flows. If a risk matrix was used, some foresters were concerned about the public reaction that might occur if or when a landscape response was greater than the risk classification suggested.

There was however, general agreement that this would be a useful avenue to pursue and that the approach should have some common elements applicable to all forestry land users (Tier 1 companies, investment forests, and woodlot owners), and there would be room to 'personalise' this for particular forest companies to meet their own requirements. Discussion on how this might be developed, what the class descriptors and thresholds might be, and how the information was to be managed and collated, was limited.

5.3 Workshop Part 2

In the afternoon session with GDC staff only (Part 2), the focus shifted to the wider perspective of forestry as a land use, its environmental effects, how forestry is represented as part of the State of the Environment monitoring network for the region, community concerns about forestry, and more general impacts on freshwater and marine environments.

There was a lot of discussion regarding the need for post-storm event analysis to document the impact of individual events, the landscape response in the short- and long-term, and the impacts of these events on slopes, waterways, infrastructure and the coastal environment, some of which were also raised in the morning session. Currently this is done on an ad hoc basis with no consistent data collection and no centralised archiving of any information that is collected. There was unanimous agreement that post-event response needs to be rapid and focused on assisting local residents who have been impacted. This would be relatively easy for large forestry companies as they tend to have measures in place to deal with such events, but was more of an issue for smaller operators or for owners of forests that had been harvested by ‘out-of-town’ contractors who essentially had ‘disappeared’. Implementing some form of bond system for owners/contractors, only to be released once the forest had reached canopy closure was discussed.

At present, GDC have a poor information base on which to quantify the effects of forestry land use or forestry activities on sediment generation, land sustainability, and its short- and long-term impacts on freshwater or marine ecosystems. However, as it is a major public concern and the number one concern for iwi, the council want to add forestry monitoring to their general State of the Environment reporting. Discussion also focused on the benefits of tree cover to reduce erosion and it was acknowledged that the region had benefitted from past interventions, particularly in the headwater forests. The focus of attention for the debris flow issue was deemed by all to be more associated with the steep Tertiary mudstone and sandstone in near coastal areas rather than the inland headwaters of the major river systems.

Four areas for future focus emerged from the general discussion and are outlined below.

5.3.1 Event preparation & post-event action

An important and perhaps critical need is to deal with a landslide-debris flow-slash mobilisation event and be better prepared for when it happens. This includes pre-event weather forecasting and aspects of early warning systems, though some of this takes place now. It was suggested that improvements were needed to information sharing both internally and externally to GDC (i.e. with forestry companies, NZTA, local communities, etc.). However, there was little time to expand on exactly what would be needed and who would take responsibility to enable this to happen.

Discussion on what post-event reporting should take place suggested further work is needed to determine in some systematic way exactly what to do, who does it, and where the information goes and how it is used. It was suggested a simple template be developed with input from forestry companies to collect post-event information. A tiered approach was suggested to identify and capture appropriate information (e.g. essential, desirable, maybe useful to collect). Such information should include as much rainfall data as possible, including that from council networks, forestry company gauges, and nearby farmers, to enable the best possible assessment of triggering and threshold conditions. The latter was identified as being important for developing any future risk matrix tool.

Understanding the drivers, spatial coverage of landsliding, and some simple analysis of number of landslides and their area would also be valuable and would enable estimates of soil loss that would be useful for more general reporting. Capturing additional information, such as the age of forests, time since harvesting, an assessment of the severity within the affected areas (High, Medium, Low), and an assessment of the consequences for downstream (High, Medium, Low), would also add value and need to be part of any approach.

5.3.2 Identifying areas unsuitable for plantation forestry

There was discussion on how to determine areas that should not be considered suitable for plantation forestry. This included identifying areas before new forests were established as well as identifying those parts of existing forests where replanting should not take place. The exact criteria for identifying such areas and development of an implementation plan for achieving this were deemed worthy of further investigation.

Trevor Freeman (GDC) briefly presented some preliminary analyses and criteria used to determine ‘hot spots’. In that analysis, several factors/criteria were used to create a map of ‘purple areas’ where the risks of future events were deemed high. These included:

- Geology – occurrence of banded mudstone and softer sandstone, Tertiary not Cretaceous lithologies, tipped trees as indicators of marginal stability, occurrence of shallow skeletal soils
- Slope analysis based on Land Resource Inventory (LRI) polygons where slopes >26 degrees are deemed to be a threshold
- Rainfall – past patterns identify three main areas of focus: Wharerata, inland Tolaga Bay and the Northern regions such as Tokararangi
- Evidence or known occurrence of past events
- Proximity to high value downstream environments, and infrastructure such as state highways, bridges, etc.

One of the problems acknowledged with this approach is the scale of analysis. The initial analysis was at 1:50,000 scale, which is useful to gain a regional perspective on where the issues were greatest, but for practical management purposes, the scale for such analyses should be at 1:10,000 or larger. This was acknowledged, and was a result of Land Use Capability (LUC) mapping being used to provide some of the underpinning data. There was some agreement that this type of approach, at the appropriate scale and with more careful selection of criteria, would be worth further development.

5.3.3 Environmental impact monitoring

As outlined earlier, one of the issues GDC is also trying to resolve is the need for land use monitoring to meet future requirements for State of Environment (SOE) reporting and the National Policy Statement for Freshwater Management National Objective Framework (NPS-FM-NOF). Forestry is currently under-represented in GDC’s SOE network (Greenwood & Unwin 2014). There are two aspects to this need. Firstly, there is a need to get a long-term view of the environmental effects of forestry in the region in order to balance the positive and negative impacts of this land use. Secondly, there is a need to deal specifically with periodic landslide-debris flow-slash mobilisation events and their impacts, particularly on freshwater and near-shore marine environments. These two aspects could be considered analogous to determining if forestry contributes to chronic and acute effects, respectively.

It was clear that data and information will be needed to meet future requirements, but discussion did not really resolve which of the two needs was the most pressing or if both were high priority. Stream health of a pine forest, pasture and native forest catchment was compared in an earlier local study across two contrasting lithologies (Te Arai and Mangaoporo catchments) (Parkyn et al. 2006) and it was suggested that using previously characterised sites would be a useful starting point. If the results from that study were deemed useful to understand the effects of plantation forestry on freshwater, it was then suggested that re-establishment of these same sites be considered to meet the general SOE need.

In terms of additional monitoring related to forestry, it was felt there was benefit in collecting information on the state of the coastal environment, in particular to assess the effects of fine deposited sediment on marine habitats. This metric has been considered to be more suitable than water clarity, at least for freshwater environments. There was also discussion on whether manuka scrub should also be considered as a 'land use' as it covers significant areas, as well as adding more 'native' reference sites, which are also underrepresented in the regional network.

5.3.4 Mitigation including risk management

Picking up on discussions from Part 1 of the workshop, a range of potential mitigations were briefly discussed including developing a risk matrix (discussed above in 5.2) and giving more attention to documenting what is working well now and why. This would help inform development of a good practice guide for post-harvest landslide/debris flow mitigation. The simplest way this could be achieved would be to work with the forestry focus group that has information on where different mitigations are being used and how effective they are.

Another need that emerged was to determine criteria that could be used to identify sites suitable for installation of mitigation measures such as slash traps. There was also discussion on the relative merits of 'live' slash traps using space planted trees to trap woody debris and reduce the erosive forces of debris flows. There was insufficient time to delve too far into other mitigation options.

6 Conclusions

Managing debris flows and post-harvest impacts is not an easy task and the best management systems cannot prevent these natural landscape processes occurring in the future. The challenge is thus to figure out how communities can <u>manage for</u> them, <u>avoid</u> them, <u>reduce</u> their number, and <u>reduce</u> the impacts that they have on downstream environments. To do that requires a better understanding by all stakeholders (including the public) about the nature of the processes, their occurrence and what conditions cause landslides and debris flows to happen.

There was wide acceptance of the need to develop some form of risk matrix to help with decision-making as well as the need to collect useful and credible information on landslides and debris flow occurrences, their impacts and what drives them. The value of a risk matrix would also be to increase the visibility and hence overall understanding of the issue, rather than necessarily provide a definitive solution to the issue.

Forestry is a key contributor to the regional economy and provides a number of benefits to soil conservation. However, it can have negative environmental impacts, many of which arise during the harvest phase of the forestry cycle. These impacts must be monitored as part of NPS-FM requirements and it is clear that significant effort will be needed to achieve this as currently, forestry land use is under-represented in SOE monitoring.

Gisborne District Council also has an issue managing the expectations of its community, many of whom have voiced considerable displeasure at the effects of forestry. Obtaining relevant, credible and defensible information to inform the public is thus a high priority.

7 Recommendations

The recommendations arising from this workshop can be grouped into six key areas:

7.1 Information gathering and review

- Collate and use existing national and local information on the environmental benefits and problems associated with forestry and endeavour to make it more widely known. This could be used to begin an awareness and education programme for the public. Use this information to help inform what the knowledge gaps are. This would include a stocktake of existing information for the Gisborne region or relevant to Gisborne region as it appears that several new staff are not aware of past work. This should start with the material compiled by Eastland Wood Council a couple of years ago, to which more recent publications could be added.
- An information system (database) needs to be developed within GDC to capture all information relevant to specific events. This doesn't necessarily mean all information needs to be archived in a single place, but will require that information from disparate sources (e.g. resource consent data, compliance data, storm event analysis) can be easily queried. This could be developed in association with the Eastland Wood Council, or between the Council and the larger forestry companies and could include future forest harvesting trends (current and projected), information on storm events, resource consent data relevant to forestry conditions and including areas not to be replanted for economic reasons.
- Identify student project opportunities – there may be aspects of either field assessments or data management that would be appropriate for a student to carry out.
- Based on the gap analysis, consider widening the scope to include a national-level perspective of the issue (debris flow problem) in conjunction with other councils who may have similar needs (Hawke's Bay Regional Council, Marlborough District Council, Taranaki District Council, Horizons Regional Council, etc.).

7.2 Develop a risk management matrix for Gisborne region

- In conjunction with the East Coast Forestry Forum, begin to scope the development of a local risk management matrix. This would require local criteria to be developed but could be a key tool in demonstrating to the public that GDC can meet public expectations for improved and consistent management of forestry activities. This could be enhanced with additional science input as required.
- Solicit interest in pursuing a joint Envirolink Tools project to develop a national risk matrix or similar tools (event templates, etc.) that can provide information to meet a broader national need but are adaptable to local conditions. This could include liaison with research providers and the NZ Forest Owners Association and the Research Levy Trust Board. Landcare Research could help facilitate this.

7.3 Environmental monitoring

- Identify information required for future monitoring and investigations (both physical and biological, and taking into account NPS-FM and RMA requirements and those that may be relevant to the marine environment). This should include long-term reference sites under native forest and mature pine forest as well as harvested areas.
- Identify potential sites of value (high consequence) that are likely to be impacted in the future, especially those where there is some historic information of past impacts, and determine a set of criteria to assess their usefulness to meet future monitoring needs.
- For SOE and/or long-term monitoring, assess previous studies to determine their potential suitability for re-establishment as future monitoring sites.
- Investigate other aspects of stream monitoring not routinely considered in regional assessment protocols. These could include habitat assessment protocols or assessment of deposited fine sediment (e.g. Clapcott et al. 2011).
- Seek Envirolink funding for a tools project to develop a nationally relevant set of guidelines, fact sheets, event templates, including risk management approaches – suggested councils – MDC, TDC, HBRC, and others.

7.4 Land zoning for future forestry

- Based on the preliminary analysis carried out by Trevor Freeman, explore and develop further criteria for identifying areas that should not be replanted in production forestry. A similar process should also be developed to determine assessment criteria for new investment forests to ensure that trees are not planted where the risk of failure following harvesting is unacceptably large. The risk management matrix criteria would provide some assistance in this development. A subsequent step would be to develop a plan for implementation within the policy setting. The NES PF may go some way to address this, but other than providing a broad scale screening tool, is unlikely to be at a scale useful for determining the highest risk areas, which are likely to be of limited extent within a forest estate.
- Any screening tool could be enhanced by developing criteria with input from the forestry sector. For instance, many of the larger companies have GIS support and LIDAR that might prove useful. Knowledge of harvesting issues, limitations to production, etc. could also inform the selection of such areas.

7.5 Education and advocacy

- Once information has been collated and reviewed, consider a campaign to raise awareness of the issue, what causes it and what the council is doing to help manage it.
- A public awareness campaign could include a range of approaches such as holding public meetings within communities previously affected by such events and inviting researchers, forestry companies and council staff to present and discuss the topic; or publishing articles in the paper or semi-popular media such as Conservation Quorum, etc.

7.6 Funding and support

- Funding avenues include Envirolink, the NZ Forest Owners Association and the Research Levy Trust Board, as well as internal GDC funding.
- In conjunction with local forestry companies via the East Coast Forestry Forum and/or the Eastland Wood Council, seek assistance to establish a regional investigation/research fund that could assist with high priority investigations.

8 Acknowledgements

We would like to thank Lois Easton GDC for commissioning this work, and providing logistical support for the workshop in Gisborne. Ian Lynn reviewed this report and Leah Kearns edited it. Members of the East Coast Forestry Forum are thanked for providing open discussion and sharing their company experiences. GDC staff who attended the workshop are similarly thanked.

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Appendix 1 – Meeting agenda

Forestry and post-harvest debris flow workshop, Gisborne District Council Tuesday December 15, 2015

Time	Activity	Who
10.00-10.15	BDO Conference Room, BDO Office Peel Street **Meet and greet**, introductions & housekeeping, purpose of workshop, expectations and house rules	Lois Easton GDC Chris Phillips Landcare Research
10.15-10.45	**What the science says** Recap on 10 points from GCFF Steeplands Workshop in November Landslide and debris flow prediction and risk analysis	Chris Phillips Les Basher Landcare Research
10.45-11.00	**East Coast Forestry Forum** Feedback on current activities and what's working	Marty Watson Chair ECFF
11.00-11.15	**RMA context** Meaning of 'effect' and what are 'Acts of God'	Trevor Freeman
11.15-11.45	**Discussion** Is a risk management approach needed and if so how do we define the risk? What risks are being considered? Is the risk perceived to be on-site, off-site, or both? Practical solutions to managing effects - Management practices to mitigate issue. What's in the toolbox? What works? What's needed? What are the current local initiatives?	All
11.45-12.00	Change venues to BNZ Partners Centre Customhouse Quay	
12.00-12.00	Lunch	
12.30-12.45	**Discussion on outcomes for the day** – where do we want to get to	All
12.45-13.00	**LUC Units** and examples of sites/recent events of concern	Trevor Freeman
13.00-15.00	**Suggested discussion topics**	
	Where the problem is – how to identify where it is. What does GDC have in its knowledge base? Where is the cut going to be and on what geology etc? What has the Forestry Forum been doing? Does the rainfall monitoring network provide adequate coverage of exotic forest areas? Practical solutions to managing effects. Turning new research/trial results into applied best practice Education and public awareness – who and how? Role of forestry forum? Environmental monitoring. Who is doing what? What else is needed? How can data be shared? Future research projects – aims, locations, timing	All
15.00-15.30	**Summary, action points & next steps**	Chris Phillips Lois Easton
15.30	**Workshop end**	

Appendix 2 – Meeting participants

Workshop Part 1	**Workshop Part 2**
Lois Easton, Shared Science Service Manager	Lois Easton, Shared Science Service Manager
James Langford, GDC	James Langford, GDC
James Sinclair, ErnslawOne Ltd	Mel Nicholls, GDC
Allan Hughes, GDC	Allan Hughes, GDC
Laura Savage, Senior Land Management Officer, GDC	Laura Savage, Senior Land Management Officer, GDC
Marty Watson, Regional Manager PF Olsen	Dennis Crone, GDC
Nicky Davies, GDC	Nicky Davies, GDC
Trevor Freeman, Environmental Services Manager, GDC	Trevor Freeman, Environmental Services Manager, GDC
Chris Phillips, Portfolio Leader, Landcare Research	Chris Phillips, Portfolio Leader, Landcare Research
Les Basher, Landcare Research	Les Basher, Landcare Research
Michael Marden, Landcare Research	Michael Marden, Landcare Research
Daniel Fraser, Hikurangi Forest Farms Ltd	

Appendix 3 – November 2015 Steepland forestry workshop field notes

Introduction

The following notes and points relate to a workshop in Gisborne November 2015 at which I was asked to comment on 'How effective are we at mitigating debris flow and sediment' as it pertains to forestry. My answer to that question was 'Not very effective', and I suggested that we may not ever be able to get to the level of mitigation that many would like us to.

The key points that follow may or may not be backed up NZ science or empirical studies. However, the principles, theories and concepts behind these points **do exist** in the literature but the empirical evidence, at least in NZ, is generally not available as the research hasn't been done. Further, my statements or key points are backed up by over 30 years' experience working in steep forested lands mostly in New Zealand but also including observations from many other parts of the world as well as being based on a legacy of similar observations and experience from current and former colleagues.

The process and the problem

Around the country there is an increasing level of concern being expressed about the environmental effects of steepland forestry. In particular, the concerns centre on the post-harvest landscape response to forest clearance and the increasing occurrence of woody debris in rivers and on beaches following intense rainstorms that generate landslides and debris flows that entrain wood and sediment. For example an event in Gisborne District contributed to $500k damage to bridges, culverts and roads as well as substantial deposition of wood and sediment on farmland. These direct costs, while significant, may pale by comparison if the loss of productive capacity of the land due to soil loss could be estimated in monetary terms. In many cases these events have an ARI around 1:10 to 1:25 years or an annual exceedance probability of 10% to 4%, i.e. the probability of a rainfall total in a given period being equalled or exceeded in any one year.

Recent and legacy articles, reports, and Environment Court evidence suggest that this phenomenon is not new and will continue into the future wherever forests are harvested or removed from steep, erosion-prone land subject to rain storms (e.g. Phillips et al. 2015; Basher et. 2015; Payn et al. 2015; Phillips et al. 2012). Essentially this is anywhere in New Zealand, though some regions, particularly North Island and the top of South Island are more vulnerable.

A starting point for beginning to manage the issue is to understand what causes the problem in the first place and the processes that contribute to the unwanted consequences. The first thing to note is that the general understanding across the industry and the regulatory environment is one of confusion in terms of the processes that contribute to the problem. There is a continuum from muddy water to debris flow and beyond and how these things are initiated and how they cease moving. There have been several different classifications of erosion and transport processes including Varnes (1978) and more recently Hunger et al. (2014). And without going into a lot of technical detail…

- A **debris flow** is defined as a 'very rapid to extremely rapid surging flow of saturated debris in a steep channel. Strong entrainment of material and water from the flow path occurs i.e. it grows'. This can be considered a **sediment transport process**. The key thing is that they carry a lot of sediment and are much more powerful and destructive than water alone.
- A **debris avalanche** or shallow landslide on the other hand is a 'very rapid to extremely rapid flow of partially or fully saturated debris on a steep slope, without confinement in an established channel'. This is an **erosion phenomenon**.

Mass movements (debris avalanches or shallow landslides or soil slips (a term in common usage in New Zealand)) become a debris flow once they become confined into a channel. Importantly there is a strong link between landslides/debris avalanches and their transition to debris flows.

Marden and Rowan (2015) put it succinctly – 'The challenge ahead lies in managing New Zealand's exotic forests within environments where storms and landslide failures are a regular occurrence and where the failure of 'natural' slopes beyond the forest boundary is more often than not the greatest contributor to stream sediment load and yield. Thus the identification and avoidance of unstable terrain, especially in those forests located in areas recognised as being geologically fragile, are critical to reducing environmental, social, and economic costs incurred by slope failures that may occur at any stage throughout a forest's rotation'.

Take-home points

1. Rainfall and runoff will not move wood off slopes – mass movements or landslides are needed to do this. Runoff on its own in a stream channel will also not generally move large woody debris – debris flows are needed.

2. Debris flows are a type of mass movement and a natural process and they occur in all steepland mountain regions throughout the world. They may or may not contain woody material derived from forests, i.e. they can be sediment-only but the distinguishing feature is that they have very high sediment concentrations by volume – in the region of 80%. This gives them particular characteristics and flow properties that separate them from other forms of mass movements (Phillips & Davies 1991). **The main point to note is that** debris flows are very erosive once channelized, they tend to erode vertically into the bed rather than laterally, and that is why they ream channels out, shift all manner of material stored in the channel and erode down to bedrock in many instances. They are significantly more erosive than water floods. As a rule, they only cease moving once the gradient changes or the flow depth reduces such as on a fan or where a steep torrent exits onto a flood plain.

3. We can't easily manage debris flows. Concrete and steel may help – hazard avoidance works in many parts of the world, i.e. recognising where they are likely to occur and the possible consequences should they do so. Where the risk to life or infrastructure is high, engineered structures such as sabo dams, bunds, defection structures, etc. may help mitigate the risk. This practice is not common in New Zealand, largely due to the cost of implementation.

4. Debris flows happen because it rains, the slopes are steep, and the landscape (soils/regolith/geology) is susceptible to mass failure. We do not know the exact conditions under which a debris avalanche or a debris flow will form but we can use observations from past events to broadly help understand this and the type of conditions that trigger them. We are also getting better with predictive tools to identify where they could occur and hence likely to occur again. This improved understanding helps with hazard zoning.

5. Understanding magnitude-frequency concepts could help policy and practitioners begin to understand the problem and what can be done about it. Annual recurrence interval (ARI) and annual exceedance probability (AEP) are useful concepts to understand.

6. Annual Recurrence Interval is the average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration.

   a. **Annual Exceedance Probability** is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

7. And there is an equation relating the two concepts. AEP is generally the preferred concept, so a 100-year ARI event will have a 1% chance of happening in any given year. A 10-year ARI has a 9.5% AEP, a 20-yr ARI a 5% AEP.

8. All slopes are not equal and all points on the slope have different threshold levels for failure. We are not likely ever to be able to say with any precision **where** on a slope a failure will occur and under what driving conditions i.e. rainfall intensities or durations. Using hindcasting we can get an idea of the likely conditions or areas that have failed in the past to inform areas that are likely to have a higher probability of failure in the future. This is hazard zoning.

9. Once trees are removed, such as by harvesting, formerly dry soils wet up and they stay wetter for longer. We find that sites that would have failed in the period when trees were not there but didn't, suddenly find they are 'ripe' for failure even in conditions where large storms do not take place (Nettleton 2005). In other words we can't stop this from happening unless we stop the trees from being removed.

10. However, if we let the trees continue to grow on for decades, such as in the native forest, what we find is that it generally will take a bigger storm to cause the treed/forested areas to fail **BUT** the size of the landslide and resulting debris flows are generally much larger (Glade 1998).

11. This explains why we can and do get landslides on cutovers in the first 1–2 years after harvesting because they are places where their time was up. When we have a very large storm coinciding with an area of cutover, we not only trigger those sites that were 'ripe', we may also trigger sites to fail that have a higher threshold. In those situations we can get failures occurring in standing or mature forests as well. These larger storms are really 'landscape-forming events' and in some cases where there are often two such storms close in time, the nature of the impact shifts between hillslope forming and channel forming.

12. We often talk about the window of vulnerability. This is a concept to try and explain the nature of the risk that exists once a forest has been harvested and before the subsequent crop reaches canopy closure. It has two aspects to it – canopy closure or occupancy and root site occupancy. Both of which are related to the density of trees on the slope. So all other things being equal, a higher density will close the window sooner but it's not necessarily that simple. The window is essentially about 5–6 years long but it could be shorter or longer depending on stocking density and other factors.

13. Even if it were physically possible to 'magic' in new seedlings immediately after the standing crop was harvested, there will still be a period for several years where those sites that would have failed but didn't because of the forest, become 'ripe' for failure and fail even in the absence of a large storm. This is all to do with magnitude-frequency concepts of landscape evolution, which suggest that the landscape does not yield continuously and stresses do not act continuously (Wolman & Miller 1960; Glade 1998).

14. What can we do about it? There has to be an acknowledgement that we cannot stop landslides and debris flows completely as these processes are natural and have shaped our landscapes. We can however try to minimise their impact. One of the ways to do this is go down a risk management pathway that includes problem avoidance – i.e. hazard understanding, thinking about what might be impacted downstream, having run-out areas or catch areas, using interception devices in some streams, and many other small things that may help **reduce** the effects resulting from slope failures that become channelized and form debris flows.

15. There has been a lot of focus on the potential for setbacks or riparian buffers to mitigate this problem, and intuitively there may be benefits. However, there currently exists no empirical evidence to support the view that wider buffers perform better. There may be a counter argument (Marden & Rowan 2015 - Whangapoua paper).

16. Alternative species, such as willows and poplar, can be used to create fences or potential slash racks on the lower parts of slopes. Personally I think that these have merit only on fans or where steep channel gradients shallow as they widen out on to fans or flood plains. Otherwise there is an increased risk of the debris flow entraining these plantings and making the problem larger.

The other thing that could be done is that if an area is recognised as having a high risk of such processes, a planned withdrawal may be one way of trying to manage future risk. However, to do that will require an assessment of the areas most at risk to landslides and debris flows from past events – e.g. hindcasting and using this to figure out where those places are.

Summary and conclusions

I read somewhere that '**Smart risk-decisions require good science. But not every risk conversation is about the evidence'.** So in summary, debris flows and landslides helped shape the landscape we find ourselves in and they will continue to do so, no matter what we do. So managing and mitigating sediment delivery from debris flows is not an easy problem to crack and we need to acknowledge this.

The challenge for us, is thus to figure out how we can **live** with them, **avoid** them, **reduce** their number, or **reduce the impacts** that they have on downstream environments and to do that requires a better understanding by us all about the nature of the processes, their occurrence and under what conditions cause the phenomena to happen.

Collecting that primary data is thus a part of what needs to happen so that we have a better understanding of the threshold conditions under which these things occur and if those thresholds vary around the country. That is the first step in being able to try and manage, what is and will always be a fundamentally very difficult thing to manage.

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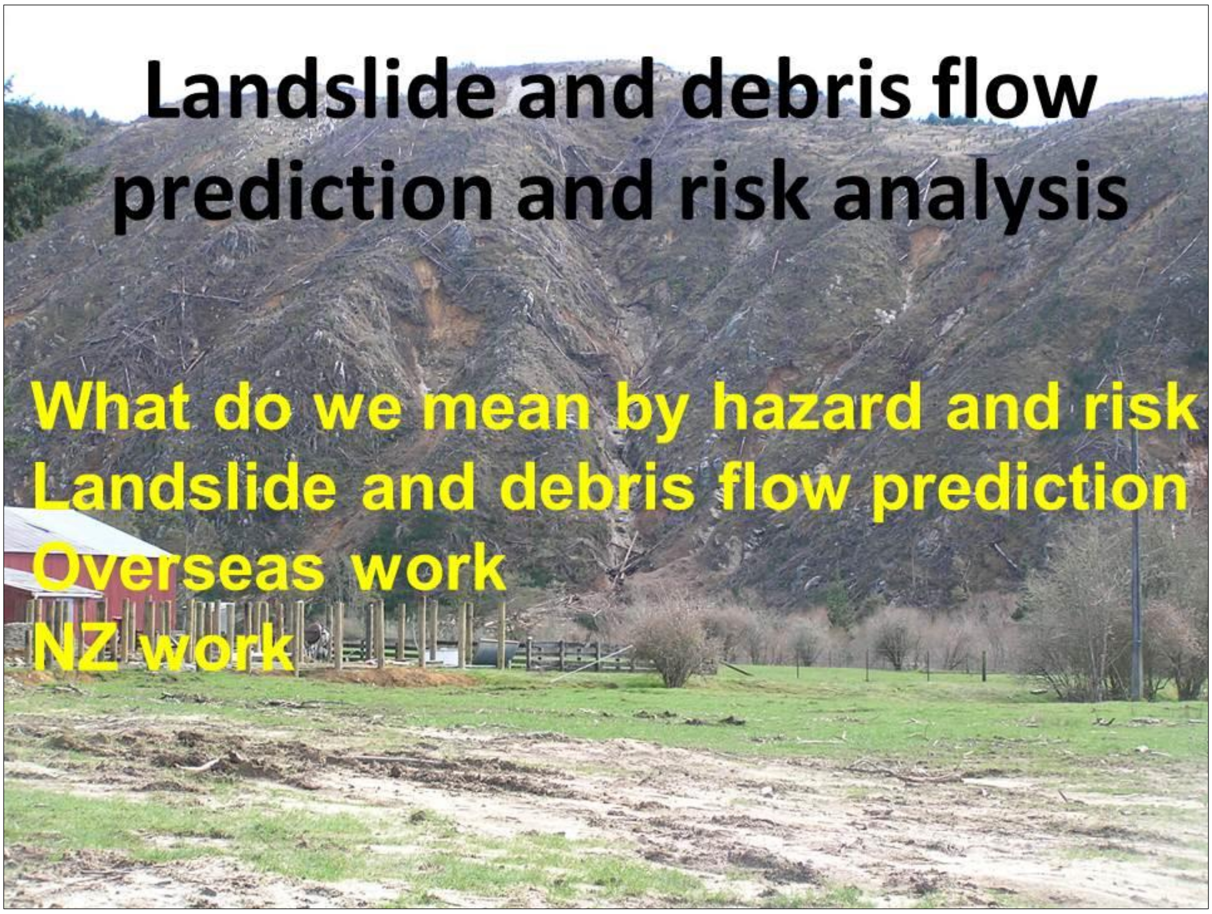
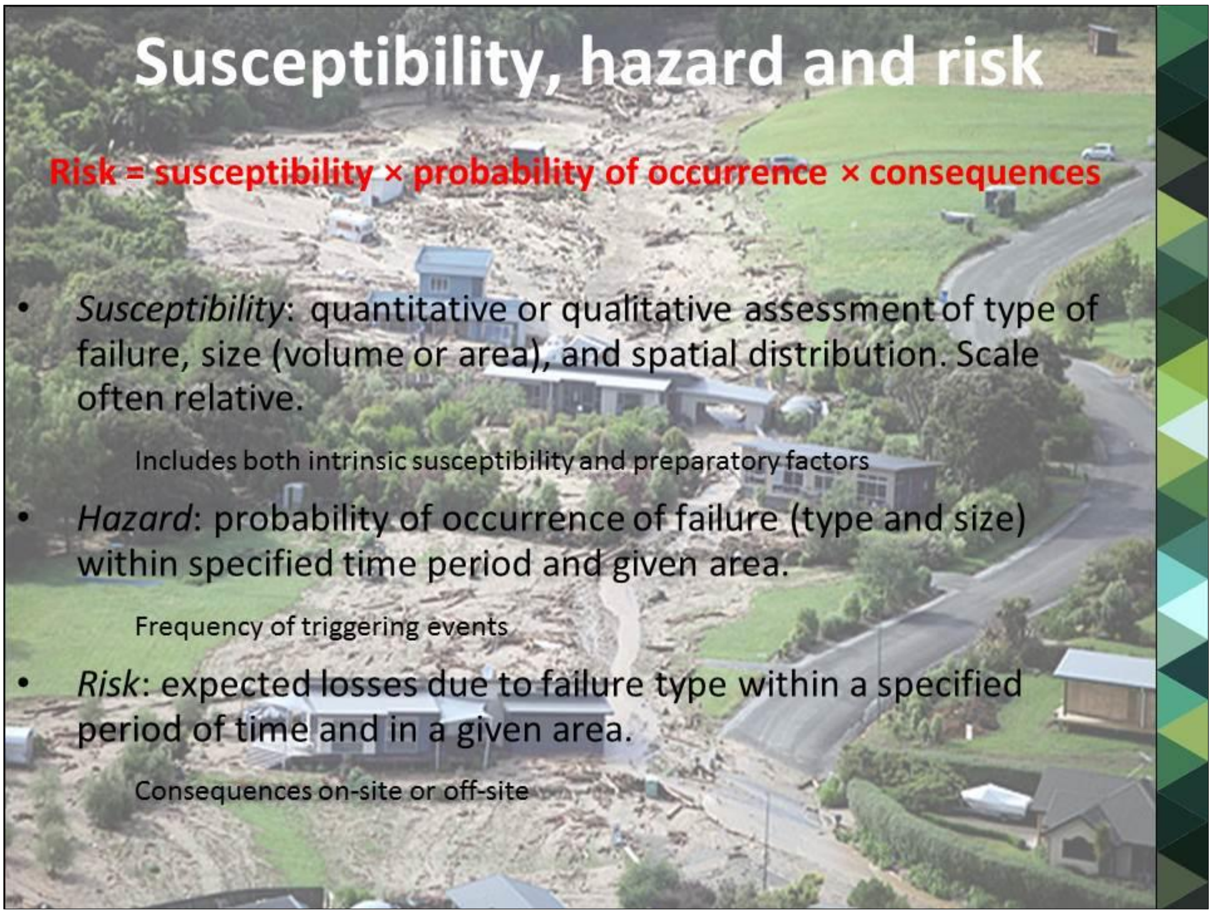
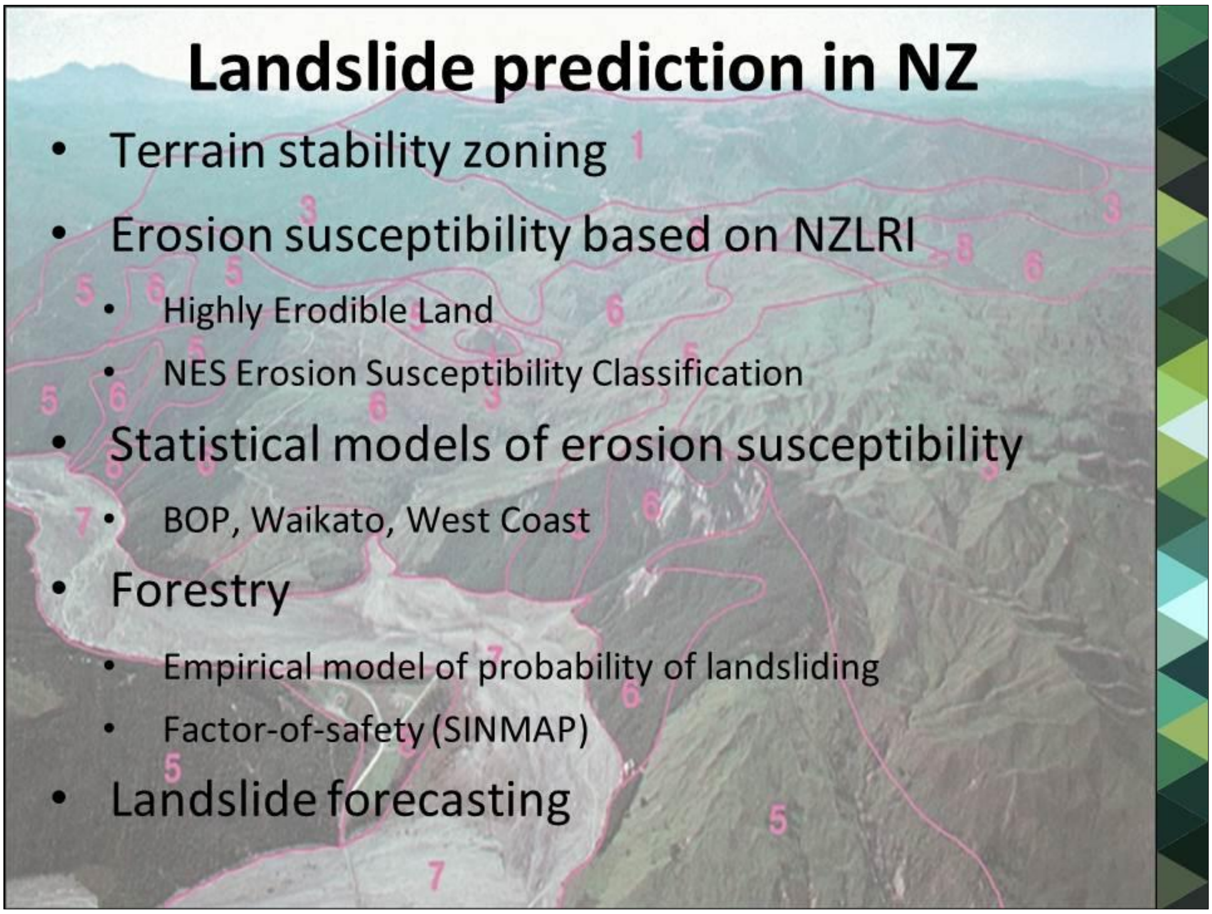
Appendix 4 – Presentation by Les Basher – 'Landslide and debris flow prediction and risk analysis'

Includes an example of a risk management matrix developed by Nelson Forests and an example of a terrain assessment developed by Hancock Forests.




Susceptibility, hazard and risk
Risk = susceptibility × probability of occurrence × consequences
• *Susceptibility*: quantitative or qualitative assessment of type of failure, size (volume or area), and spatial distribution. Scale often relative.
Includes both intrinsic susceptibility and preparatory factors
• *Hazard*: probability of occurrence of failure (type and size) within specified time period and given area.
Frequency of triggering events
• *Risk*: expected losses due to failure type within a specified period of time and in a given area.
Consequences on-site or off-site


Landslide prediction in NZ
• Terrain stability zoning
• Erosion susceptibility based on NZLRI
• Highly Erodible Land
• NES Erosion Susceptibility Classification
• Statistical models of erosion susceptibility
• BOP, Waikato, West Coast
• Forestry
• Empirical model of probability of landsliding
• Factor-of-safety (SINMAP)
• Landslide forecasting

Probability of triggering events

- Landsliding and debris flows typically triggered when a rainfall threshold is exceeded
- Several NZ attempts to define rainfall thresholds for landsliding

  Annual rainfall, daily rainfall, rainfall intensity, antecedent moisture

- Research suggests relationships between rainfall intensity, rainfall duration, antecedent rainfall and landslide occurrence are complex and can only be characterised probabilistically rather than mechanistically.

Landslide susceptibility assessment

- First step in assessing risk
- Numerous studies internationally (although not so much for forestry)
- Types of approaches
  - Heuristic zoning
  - Statistical methods
  - Process-based methods (typically FoS-based)
- A landslide inventory is typically used to underpin the analysis
- Typical controlling factors
  - Predisposing (geology, soils, topography, hydrology)
  - Triggering (rainfall, landcover change)

Terrain stability zoning, British Colombia

Use a system of reconnaissance and detailed terrain stability assessment

Reconnaissance terrain stability class	Interpretation
S *does not need to be mapped*	• Stable. There is a negligible to low likelihood of landslide initiation following timber harvesting or road construction.
P	• Potentially unstable. • Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction.
U	• Unstable. Natural landslide scars present. • Expected to contain areas where there is a high likelihood of landslide initiation following timber harvesting or road construction.

Detailed terrain stability mapping classes, British Colombia

Terrain stability class	Interpretation
I	• No significant stability problems exist.
II	• There is a very low likelihood of landslides following timber harvesting or road construction. • Minor slumping is expected along road cuts, especially for 1 or 2 years following construction.
III	• Minor stability problems can develop. • Timber harvesting should not significantly reduce terrain stability. There is a low likelihood of landslide initiation following timber harvesting. • Minor slumping is expected along road cuts, especially for 1 or 2 years following construction. There is a low likelihood of landslide initiation following road construction.
IVR	• Expected to contain areas with a moderate likelihood of landslide initiation following road construction and a low or very low likelihood of landslide initiation following timber harvesting.
IV	• Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction.
V	• Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction.

Likelihood of Occurrence	Qualitative Description	Annual probability of occurrence[4]	Probability of occurrence over a 20 year term
Very High (VH)	An event is imminent or likely to occur frequently; well within the lifetime of a typical forest road[2] or soon after logging[3].	>0.05 (>1/20)	>0.65
High (H)	An event can happen or is probable within the lifetime of a typical forest road[2] or soon after logging[3].	0.01 - 0.05 (1/100 - 1/20)	0.18 - 0.64
Moderate (M)	An event is not likely, but possible within the lifetime of a typical forest road[2] or soon after logging[3].	0.002 - 0.01 (1/500 - 1/100)	0.04 - 0.18
Low (L)	An event is unlikely to occur (remote possibility) within the lifetime of a typical forest road[2] or soon after logging[3].	0.0004 - 0.002 (1/2500 – 1/500)	0.01 - 0.04
Very Low (VL)	The likelihood of an event occurring is extremely remote to nil within the lifetime of a typical forest road[2] or soon after logging[3].	<0.0004 (<1/2500)	<0.01

Risk management matrix used in British Colombia

		Consequence			
		High	Medium	Low	Very low
Landslide hazard	High	High	High	Medium-high	Medium-high
	Medium	High	Medium	Medium	Low
	Low	Medium	Medium	Low	Low
	Very low	Low	Low	Low	Very low

Decision Matrix proposed by Bloomberg et al. (2011) for determining level of risk analysis required

Erosion Susceptibility Class	<0.08	0.08 - 0.12	0.12 – 0.21	0.21 – 0.30	>0.30	AEP
	>12	8	4.3	2.8	<2.8	ARI (yrs)
Low	NA	NA	NA	NA	NA	
Moderate	NA	NA	SA	SA	SA	
High	SA	SA	FA	FA	FA	
Very High	FA	FA	FA	FA	FA	

NA = No risk analysis required to proceed
SA = Some risk analysis required
FA = Proceed under stringent conditions only if full risk analysis indicates risk can be managed to be acceptable

Risk Management Matrix, Nelson Forests

- Susceptibility
  - Geology, slope, catchment size, proximity to streams
- Hazard
  - Hourly and daily rainfall intensity, AEP, observed frequency of landslides
- Consequences
  - People, property, ecology, cost, reputation
- Susceptibility and hazard combined to estimate likelihood of landslides entering streams
  - Rare → almost certain
- Then combined with consequences to assess overall risk
  - Negligible, low, moderate, high

Likelihood of Landslides entering streams	Susceptibility: Geology, slope & proximity to channel				Probability	Observed Frequency	
	Granites/Schist	Greywacke	Gravels	Loess			
	Majority of slopes > 45° < 30 m from stream & lead directly into channel watershed area > 0.5ha	Majority of slopes >45° < 30m from stream and lead directly into channel watershed >0.5ha	N/A	N/A	> 75mm/hr intensities AEL less than 0.05 > 300mm /24hr , AEL < 0.05 OR specific locations in region	Has occurred at more than once in last 10 years	***Almost certain***
	Majority of slopes 20 to 45° < 30 m from stream & lead directly into channel watershed area > 0.5ha	Majority of slopes 20 to 45° < 30m from stream and lead directly into channel watershed >0.5ha	Majority of slopes > 45° < 30 m from stream and lead directly into channel	Majority of slopes > 45° < 30 m from stream and lead directly into channel	>75mm/hr intensities AEL less than 0.05 > 300mm /24hr , AEL < 0.05 OR specific locations in region	Has occurred but no more than once in last 20 years	***Likely***
	Majority of slopes 30-45° > 30m from channel OR watershed area < 0.5 ha	Majority of slopes 30-45° > 30 meters from channel OR watershed area < 0.5 ha	Majority of slopes 20 to 45° < 30m from stream and lead directly into channel watershed >0.5ha	Majority of slopes 20 to 45° < 30m from stream and lead directly into channel watershed >0.5ha	> 75mm/hr intensities AEL greater than 0.05 > 300mm /24hr , AEL > 0.05 OR specific locations in region	Has occurred in the memory of the locals	***Possible***
	Majority of Slopes 20-30° > 30m from stream	Majority of slopes 20 to 30° > 30 meters from stream	Majority of slopes 30-45° > 30 meters from channel OR watershed area < 0.5 ha	Majority of slopes 30-45° > 30 meters from channel OR watershed area < 0.5 ha	> 75mm/hr intensities AEL greater than 0.05 > 300mm /24hr , AEL > 0.05 OR specific locations in region	Records or local knowledge indicates an occurrence in last 50 years	***Unlikely***
	Majority of Slopes <20°	Majority of slopes < 20°	Majority of slopes 20 to 30° > 30 meters from stream OR slopes less than 20°	Majority of slopes 20 to 30° > 30 meters from stream OR slopes less than 20°	> 75mm/hr intensities AEL greater than 0.05 > 300mm /24hr , AEL> 0.05 OR specific locations in region	No record of it having ever occurred in last 50 years	***Rare***

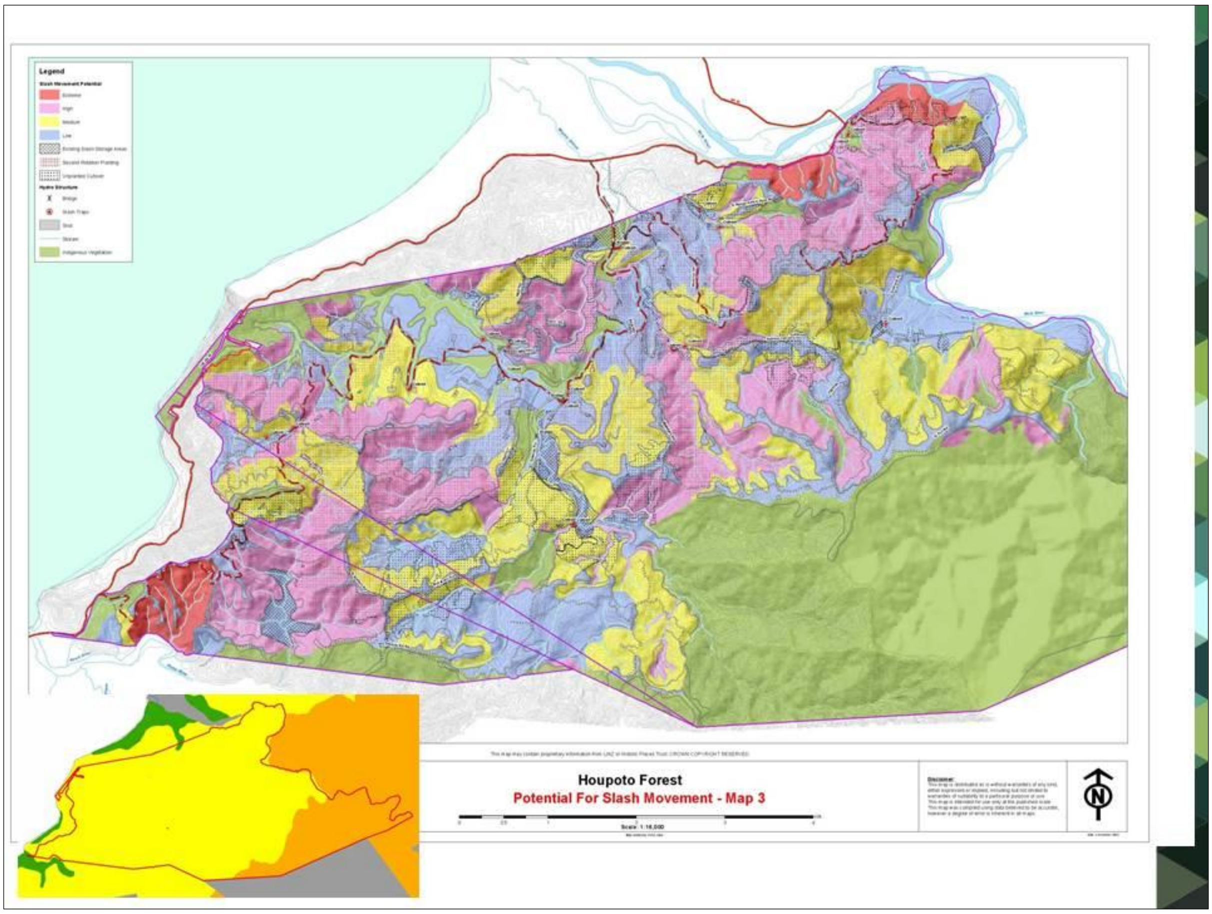
	Consequence of landslides (entering streams)				
People	No roads or buildings in floodplain < 3km below the site: No-one affected	Rarely used (< monthly) access tracks or buildings exist in the floodplain < 3km below the site Inconvenience to people	Infrequently used (< weekly) access tracks or buildings exist in the floodplain < 3 km below the site. Injury or first aid treatment	Regularly used (daily) tracks or buildings exist in the floodplain <3km below the site Injury requiring treatment by medical practitioner	Presence of public road or dwellings directly below the site without reliable mitigating circumstances (barriers) with risk of major injury or fatality
Property (buildings, bridges)	No roads or buildings in floodplain < 3km below the site: No-one affected	< 5 properties below ALL sites within the catchment to be harvested over 4 yr period AND only fence lines within the floodplain	< 5 properties below ALL sites within the catchment to be harvested over 4 yr period AND bridges, roads and farm buildings within the floodplain	> 5 properties below ALL sites within the catchment to be harvested over 4 yr period AND bridges, roads and farm buildings within the floodplain	Presence of buildings or infrastructure directly below the site with no reliable mitigation available: significant damage Public roads closed.
Ecology	No soil or debris from the site has potential to directly enter ephemeral or permanent streams (land above terrace, infill or fan)	Soil from the site could directly enter an ephemeral stream	Soil from the site could directly enter a permanent stream	Soil from the site could directly enter a Class 1 or 2 stream	Class 1 or 2 streams directly below the site where ecological loss is reasonably expected to occur (dead fish)
Economics	Only routine maintenance within NF property required	>NZD$10,000 clean up costs	>NZD$50,000 clean up costs	> NZD$250,000	Potential for > NZD $1,000,000 of offsite damages
Reputation	Not visible form neighbours or public	occasional debris flows obscured from public view	numerous visible debris flows across private land	widespread visible debris flows across public or private land	Consequence of landslides at this location is likely to generate National / Regional concern and sustained adverse media
	Insignificant	**Negligible**	**Moderate**	**Extensive**	**Significant**

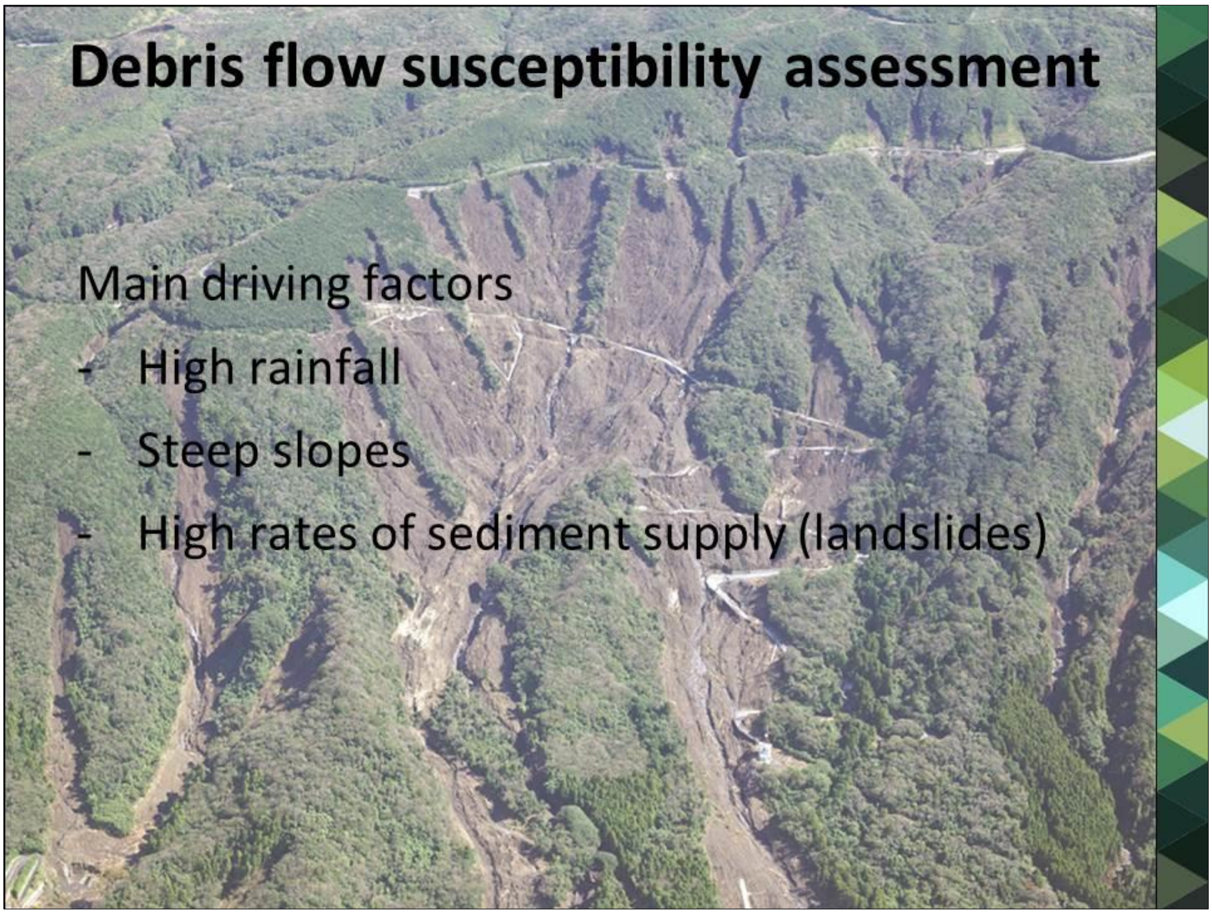
Slash mobilisation risk, Houpotu Forest Hancock Forest Management

Considers

- Slope
- Geology
- Soil
- Erodibility
- Slash storage

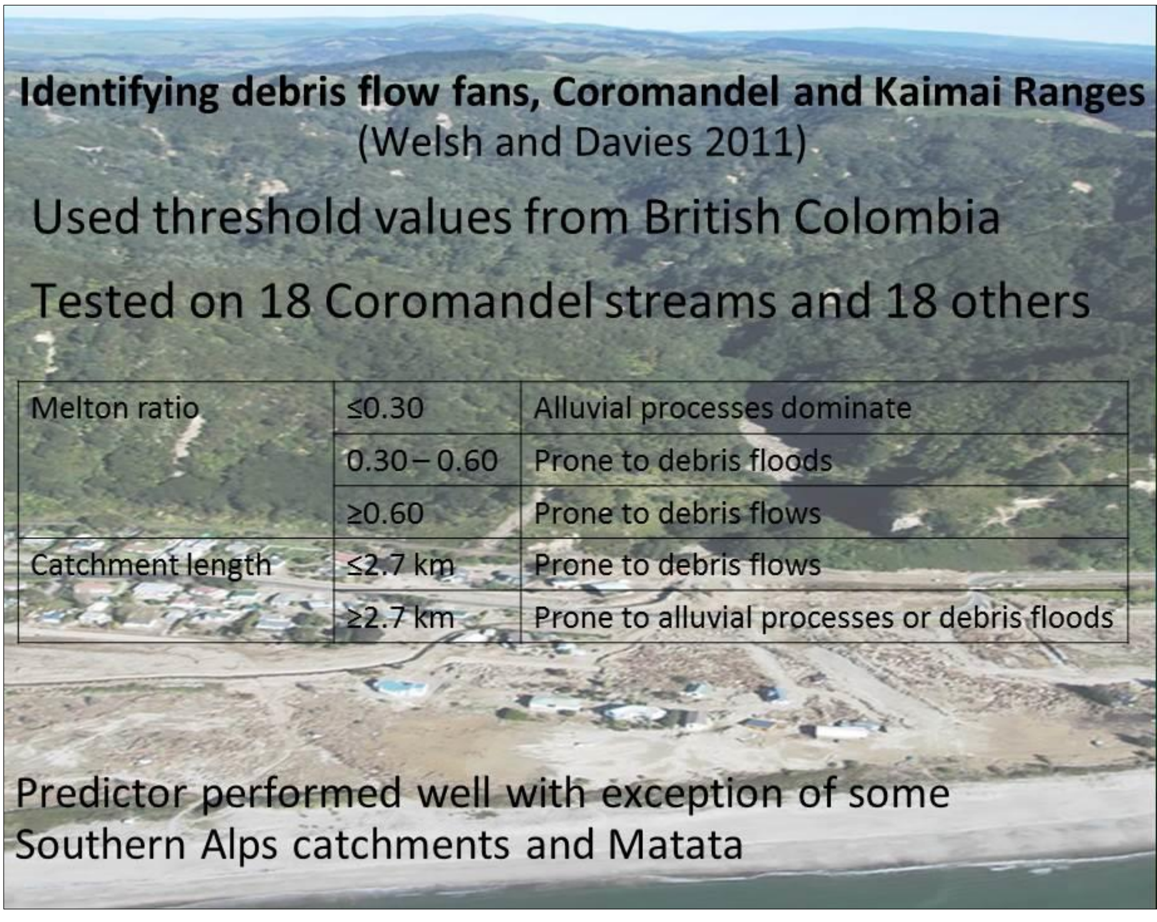
4 classes defined – low, medium, high, extreme


Houpoto Forest
Potential For Slash Movement - Map 3


Debris flow susceptibility assessment
Main driving factors
- High rainfall
- Steep slopes
- High rates of sediment supply (landslides)

Key predictors to identify debris flow fans

- Catchment characteristics (topography, area, length)
- Flow accumulation, stream power index, topographic wetness index
- Metrics used to distinguish debris flow fans from alluvial and debris flood fans
- Most common predictors
  - Melton ratio $(\mathrm{R}/\sqrt{A})$
  - Catchment length



Identifying debris flow fans, Coromandel and Kaimai Ranges
(Welsh and Davies 2011)

Used threshold values from British Colombia

Tested on 18 Coromandel streams and 18 others

Melton ratio	≤0.30	Alluvial processes dominate
	0.30 – 0.60	Prone to debris floods
	≥0.60	Prone to debris flows
Catchment length	≤2.7 km	Prone to debris flows
	≥2.7 km	Prone to alluvial processes or debris floods

Predictor performed well with exception of some Southern Alps catchments and Matata

Summary

Susceptibility, hazard and risk should be evaluated independently

Heuristic or quantitative approach could be pursued

A fit-for-purpose approach is needed (i.e. forestry-specific)

Better data on occurrence of landslides and debris flows needed