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Technical Report

Impacts on Marine and Freshwater Environments from Plantation Forestry

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EXECUTIVE SUMMARY

Sedimentation in marine and freshwater environments from forested hillslopes in the Marlborough and Tasman districts is a problem, with the potential to cause significant adverse environmental effects. In particular, large infrequent events such as landslides and debris flows have great potential to cause long-term significant adverse environmental effects. Both councils have invested substantially in the understanding of the potential risks from sediment on marine and freshwater environments, by understanding the predisposing factors that led to sediment discharges, landslides, and debris flows. However, methods to rank the effects of these events by their likelihood is limited. There have been many well-documented occurrences of large-scale movements of mud, rock, and woody debris originating from commercial forestry catchments across Tasman and Marlborough and associated adverse effects.

There is a broad acceptance that forestry operators need to manage the risk of landslides and debris flows, along with avoiding the effects of sedimentation, as now required under the National Environmental Standard for Plantation Forestry (NESPF). However, the guidance on whether forestry activities will result in such effects and require resource consent under the NESPF is very limited. Managing these risks with confidence is limited by a critical lack of essential data and information to inform where and what mitigations can be employed (sources, extent, frequency) and risk management of the effects (environmental, social, and economic). This report focuses on the environmental component of these risks.

A high-level review of scientific literature was undertaken to identify the causes and consequences of adverse effects from forestry in the Marlborough and Tasman districts. This review does not attempt to repeat some of the more substantial reviews completed, rather it uses these to highlight the occurrence and effects of forestry activities on marine and freshwater. These effects include the smothering of freshwater estuarine and marine habitats by fine sediment, other direct and indirect effects on freshwater and marine life, discolouration of the water column, deposition of woody debris, and destruction of property. This review highlights the predisposing factors of the Marlborough and Tasman environment that result in inevitable potential adverse effects from forestry activities, primarily harvesting. In part, this is due to the periodic occurrence of high-intensity rainfall events, and the nature of the underlying lithology and soils.

This report discusses the current regulatory framework that applies for forestry activities in Marlborough and Tasman areas and exemplifies through implementation of the NPSPF the ambiguity of permitted standards by critiquing regulations within the NESPF related to sediment. This report attempts to provide insights on additional regulatory tools for the MDC and TDC to assess as possible tools in implementing the NESPF, that we think in collaboration with scientists, resource management practitioners, stakeholders, and foresters can give decision-makers and foresters more certainty that effects from forestry are appropriately avoided or mitigated in highly valued environments.

It is clear from a review of the relevant regional plans, the rules in these plans that are more stringent and prevail over the NESPF are relevant to the highly valued coastal and freshwater environments of Marlborough and Tasman. It is therefore recommended that the MDC and TDC proceed jointly with developing their own consistent tools for making assessments of activities considered to meet permitted standards and if consent is required, to ensure that the identified possible effects will meet standards with their Regional Plans and the Objectives and Policies of the NESPF.

1. SCOPE AND STRUCTURE OF THIS REPORT

This report contributes to an Envirolink large grant advice project, "Operational-level landslide hazard identification and risk management to better manage the risk of erosion from harvested plantations on slopes". The scope of this report is therefore to:

1) Summarise the standards and or guidelines related to the relevant statutory documents, including the National Environmental Standard for Plantation Forestry (2017), New Zealand Coastal Policy Statement (2010) and National Policy Statement Freshwater (2020), as well as the relevant regional planning documents.
2) Provide an overview of the available existing knowledge on what the impacts are for marine and freshwater environments from sediment and organic debris (slash) originating from plantation forestry sites in Tasman and Marlborough Districts.
3) Provide an overview of relevant risk assessment tools to support the development of methods for assessing whether the characterised impacts from plantation forestry will meet standards, and or can be practicably mitigated for freshwater and marine environments that will support regional councils and decision-makers.

Section 2 outlines the relevant statutory documents as they relate to plantation forestry, with a brief overview of the National Policy Statement for Freshwater (NPSFM) and the New Zealand Coastal Policy Statement (NZCPS). A description of the relevant regulations from the National Environmental Standard for Plantation Forestry (NESPF) is provided and discussed with respect to rules relevant to sediment and water clarity. An overview of the regional plans for the Marlborough District Council (MDC) and Tasman District Council (TDC) is provided for those rules with standards related to sediment and water clarity, and forest activities.

Section 3 provides a brief overview of the potential impacts of plantation forestry on freshwater and marine environments, with a focus on impacts originating from sediment transport, and organic debris (forestry slash). The intent of this report is not to repeat previous publications that have already reviewed at length and reported on the effects of forestry-related activities that can increase the frequency and impacts of soil erosion (see: Urlich, 2015). Rather, case study areas are used to exemplify the process for assessing the effects of plantation forestry which includes identifying the values within the case study areas and likely effects based on historic events.

Section 4 of this report reviews the usefulness of a potential risk-based assessment approach to plantation forestry and the possible impacts. This includes a brief review on utilising a risk matrix system that is tailored for environmental consequences, and in future will seek input from council planning staff into the classification of consequences (i.e., catastrophic to insignificant). The purpose of this part of the project is to develop an efficient and effective method for assessing the severity of the characterised impacts (consequences) and whether the impacts will meet standards and or can be practicably mitigated for freshwater and marine environments to support regional councils and decision-makers.

2. STATUTORY FRAMEWORKS

At a planning and regulatory level, the highest level of policy direction occurs with the Resource Management Act (RMA), the New Zealand Coastal Policy Statement (2020) (NZCPS), and the National Policy Statement for Freshwater Management (2020) (NPSFM). These high-level documents set the framework for the more direct regulation that is contained in the National Environment Standard for Plantation Forestry (NESPF) and relevant provisions of regional and district plans.

Until the NESPF came into force in May 2018, the rules governing forestry activities were provided solely in district and regional council plans. These more local rules were designed to take into account local environmental conditions and community priorities. Therefore, the new national regulations were designed to provide a nationally consistent set of regulations. Rules in district or regional plans can be more stringent than the NESPF rules. The NESPF regulates eight core forestry activities. The NESPF is underpinned by an erosion susceptibility classification (ESC) framework (Bloomberg, 2011; Basher *et al.,* 2015). The ESC classes frequently determine if a forestry activity is a permitted activity (no resource consent required if conditions complied with) or whether a resource consent is required. The NESPF also categorises forestry activities into one of the following RMA resource consent categories: controlled, restricted discretionary, or discretionary. The regulations apply to any forest larger than one hectare that has been planted specifically for commercial purposes and harvest. In the following section the NESPF is described and a critique of regulations related to sediment is provided.

Forestry in the Marlborough district is also currently regulated under the Marlborough Sounds Resource Management Plan (MSRMP), the Wairau/Awatere Resource Management Plan (WARMP) and the Proposed Marlborough Environment Plan (pMEP). Forestry in the Tasman district is managed under the Tasman Resource Management Plan (TRMP).

2.1 New Zealand Coastal Policy Statement (2010)

The NZCPS applies to forestry activities in coastal environments with a suite of provisions that are relevant to the development of regional and district plans as well as resource consent applications. Under the NZCPS, three objectives are particularly relevant to forestry.

Objective 1

"To safeguard the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries, dunes and land, by:

- *maintaining or enhancing natural biological and physical processes in the coastal environment and* *recognising their dynamic, complex and interdependent nature;*

- *protecting representative or significant natural ecosystems and sites of biological importance and maintaining the diversity of New Zealand's indigenous coastal flora and fauna; and*
- *maintaining coastal water quality, and enhancing it where it has deteriorated from what would otherwise be its natural condition, with significant adverse effects on ecology and habitat, because of discharges associated with human activity."*

Objective 2

"To preserve the natural character of the coastal environment and protect natural features and landscape values through:

- *recognising the characteristics and qualities that contribute to natural character, natural features and landscape values and their location and distribution;*
- *identifying those areas where various forms of subdivision, use, and development would be inappropriate and protecting them from such activities; and*
- *encouraging restoration of the coastal environment."*

Objective 6

"*To enable people and communities to provide for their social, economic, and cultural wellbeing and their health and safety, through subdivision, use, and development, recognising that:*

- *the protection of the values of the coastal environment does not preclude use and development in appropriate places and forms, and within appropriate limits;*
- *some uses and developments which depend upon the use of natural and physical resources in the coastal environment are important to the social, economic and cultural wellbeing of people and communities;*
- *functionally some uses and developments can only be located on the coast or in the coastal marine area;*
- *the coastal environment contains renewable energy resources of significant value;*
- *the protection of habitats of living marine resources contributes to the social, economic and cultural wellbeing of people and communities;*
- *the potential to protect, use, and develop natural and physical resources in the coastal marine area should not be compromised by activities on land;*
- *the proportion of the coastal marine area under any formal protection is small and therefore management under the Act is an important means by which the natural resources of the coastal marine area can be protected; and*
- *historic heritage in the coastal environment is extensive but not fully known, and vulnerable to loss or damage from inappropriate subdivision, use, and development*."

The NZCPS is relevant to forestry as it contains direction on activities within the coastal environment. There are specific policies which require significant effects on biodiversity to be avoided, remedied, or mitigated (Policy 11), and ecological implications related to the management of harmful aquatic organisms (Policy 12) avoided. Policy 13 sets out the preservation of the natural character of the coastal environment, and Policy 15 sets out the protection of these natural features and natural landscapes.

Sedimentation is specifically addressed under Policy 22, which requires assessment and monitoring of sedimentation levels and impacts. It also requires controls on the effects of land-based activity (subdivision and development, forestry, and others) that can increase the discharge of fine sediments and sediment deposition in coastal habitats.

Policy 22: Sedimentation

1. *"Assess and monitor sedimentation levels and impacts on the coastal environment.*
2. *Require that subdivision, use, or development will not result in a significant increase in sedimentation in the coastal marine area, or other coastal water.*
3. *Control the impacts of vegetation removal on sedimentation including the impacts of harvesting plantation forestry.*
4. *Reduce sediment loadings in runoff and in stormwater systems through controls on land use activities."*

Policy 23 sets out matters to have particular regard to when managing the discharge of contaminants.

2.2 National Policy Statement for Freshwater Management (2020)

The NPSFM 2020 sets out national-level objectives and policies that regional councils must 'give effect to' in their planning documents, including by setting targets and limits for maintaining or enhancing water quality and the ecological health of water bodies over time. The NPSFM sets a requirement to manage freshwater in a way that 'gives effect' to Te Mana o te Wai through a new hierarchy of obligations that prioritises the health and wellbeing of water bodies, then the essential needs of people (e.g., drinking water), followed by other uses.

The NSPFM explains the concept of Te Mana o te Wai as "*Te Mana o te Wai is a concept that refers to the fundamental importance of water and recognises that protecting the health of freshwater protects the health and well-being of the wider environment. It protects the mauri of the wai. Te Mana o te Wai is about restoring and preserving the balance between the water, the wider environment, and the community."*

The NPSFM 2020 establishes a framework to improve degraded freshwater bodies and maintain or improve all others that are implemented through regional and district plans that must give effect to the NPSFM and the resource consent process where decision-makers must have regard to the NPSFM provisions. These provisions include a complex suite of water quality "standards" defined in the National Objective Framework (NOF). These include specific water quality "attributes" (measurable characteristics of water) that incorporate national bottom lines (minimum standards). Of the relevant attributes aimed at providing for ecosystem health, suspended fine sediment is included as an attribute requiring a limit on resource use, and deposited fine sediment is included as an attribute requiring action plans in regional plans.

Historically sediment management has been controlled through BMPs and limited suites of regional rules. Now the NPSFM applies to forestry activities for managing the effects of sediment on freshwater. Regional councils are required to achieve these targets within their regions primarily by amendment to regional plans, the resource consent process, and non-regulatory methods. This will have important implications for the forestry sector as sediment is the main contaminant of concern resulting from plantation forestry activities.

Two new attributes require management under the NPSFM NOF. These are suspended fine sediment and deposited fine sediment. Each attribute is accompanied by a national bottom line for its concentration in different water bodies, depending on the class of the specific waterbody. The classes for specific waterbodies reflect the New Zealand River Environment Classification (REC) that spatially defines reaches of a water body based on climate, source of flow, geology, landcover, position in the river network, and valley landform. Based on the combination of the first three variables (climate, source of flow and geology) a numerical limit on suspended fine sediment and deposited fine sediment is given in the units of visual clarity (m) and percentage (%) of fine sediment cover, respectively.

In the cabinet paper on the Action for Healthy Waterways package, approximately 31% of New Zealand's monitored sites are reported to not meet the new bottom lines for sediment and will require improvements (Cabinet Paper, 2020). Therefore, the inclusion of sediment in the NPSFM 2020 will likely result in increased regulation of the forestry sector to manage sediment-related effects from plantation forestry activities.

2.3 National Environmental Standard for Plantation Forestry (2017)

The NESPF came into force on 1 May 2018. The NESPF generally prevails over RMA plan rules for managing the environmental effects of plantation forestry, except where councils have more stringent plan rules (for specific reasons such as managing sensitive receiving environments). Under the NESPF plantation forestry activities do not require a resource consent where permitted activity conditions are complied with. Situations where resource consent applications are required include where a forestry activity is in a high-risk area, as described by the risk management tools incorporated in the NESPF (e.g., the Erosion Susceptibility Classification tool, the Wilding Tree Risk Calculator, and the Fish Spawning Indicator). The Ministry for the Environment has stated that the purpose of the NESPF is "to maintain or improve the environmental outcomes associated with plantation forestry activities nationally and to increase the certainty and efficiency of managing plantation forestry activities". The NESPF regulations cover the following eight core plantation forestry activities that have potential environmental effects.

- Afforestation.
- Pruning and thinning to waste.
- Earthworks.
- River crossings.

- Forest quarrying.
- Harvesting.
- Mechanical land preparation.
- Replanting.

It is not yet clear whether the NESPF will be amended to reflect the sediment management provisions of the NPSFM 2020, and the new numerical attributes related to suspended fine sediment and deposited sediment. We think it is most likely that the two statutory instruments will be largely left to function in a complementary manner with regional councils having specific regional responsibilities to assess the need for more stringent rules to ensure the achievement of specific freshwater quality attributes in specific catchments.

The NESPF includes numerous regulations designed to manage sediment discharges from various plantation forestry activities. As of January 2021, we understand that the relevant regional councils have modified regional plans to be consistent with the NESPF provisions. Under the NESPF, Regulations 26, 56, 65, 74(6) and 90 are permitted activity conditions relating to the effects of sediment discharges in receiving waters. Under these regulations, sediment originating from forestry activities must be managed to ensure that, after reasonable mixing, the activity does not give rise to any of the following effects in receiving waters:

- Any conspicuous change in colour or visual clarity.
- The rendering freshwater unsuitable for consumption by farm animals.
- Any significant adverse effect on aquatic life.

2.3.1 NESPF Implementation Challenges

Regulations 26, 56, 65, 74(6) and 90 in the NESPF are specified as standards for permitted activities, but as the threshold is subject to "reasonable mixing" and "conspicuous change in colour or visual clarity" this needs to be determined on a site-by-site basis. This is recognised in NESPF guidance released by the Ministry for Primary Industries (MPI), although specific guidance for making site-by-site assessments is not provided.

The terms "reasonable mixing" and "conspicuous change" have been used in environmental law in New Zealand since the Water and Soil Conservation Act 1967 (SWCA) (Simpson Grierson, 2010), that typically dealt with point source discharges and not the non-point sources that are a key focus of current water quality issues in New Zealand. There is some case law to assist interpretation of reasonable mixing and conspicuous change. In *Southland Regional Council v New Zealand Deer Farms* the court considered that the "size of the waterway, velocity of water, tributaries and the like" were factors to consider, and found that the numerical reasonable mixing zone in the Plan could not be applied because of the need for a case-by-case approach rather than a blanket zone for all activities and waterways. In *Paokahu Trust v Gisborne District Council* the court stated that "reasonable mixing was held to be a question of fact".

These above interpretations are relevant. However, those cases related to significant point source discharges and we consider that it will be challenging to apply these principles to small waterways and catchments with multiple areas of largely diffuse discharges of sediment to freshwater bodies and/or coastal water. It is likely that in these situations there will be interpretation disagreements about what constitutes reasonable mixing and how conspicuous changes should be determined. When considering the implementation of the sediment related regulations, the above criticism of the NESPF sediment regulations suggests that tools for implementing the NESPF are needed. Considering the current lack of tools, Councils are likely to continue to develop and use their own guidelines to help interpret NESPF permitted thresholds relating to the effects of sediment discharges in receiving waters. Therefore, there may be a lack of national consistency if the implementation of these permitted threshold matters differs between regional councils.

A comprehensive assessment of risk factors and implementation of all the relevant measures would provide council certainty that all measures are in place for an activity to remain permitted under the regulations to ensure ongoing compliance. There is guidance for councils on the assessment of management plans and the content of these in terms of adequately complying with the permitted activity requirements. If the necessary management practices are in place, the effects of sediment discharge on any receiving water would be appropriately avoided or mitigated. A council may have evidence that the NESPF permitted activity regulations do not or would not ensure achievement of NPSFM bottom lines or regional plan water quality attributes. A regional council could then implement new regional plan rules that relate more specifically to the best practice management that would achieve specific environmental outcomes/water quality attributes.

The NESPF enables the local authority to have more stringent rules in place to protect marine and freshwater in the areas like the Marlborough Sounds and Tasman Region. If a council is concerned that the uncertainties associated with "reasonable mixing" and "conspicuous change" are contributing to a deterioration in water quality, then there would be grounds for the development of either specific guidance on the measures necessary to ensure the avoidance of conspicuous change after reasonable mixing. If such guidance is not effective, then a council can develop more stringent rules in a regional plan. This would normally take the form of a set of regional plan rules that specify the physical measures to be taken and associated activity class definitions (i.e., permitted activity, controlled activity, restricted discretionary activity, etc.) to ensure that adverse effects would be avoided or adequately mitigated. This may result in more applications for resource consents to allow a specific case by case assessment to determine what is needed to ensure downstream water quality outcomes/water quality attributes are achieved.

The waterway characteristic details that the NPSFM sediment national bottom line utilises may be an opportunity for those making assessments on resource consent requirements, compliance, and appropriate avoidance or mitigation of possible environmental effects to fine-tune requirements to a specific subject site. The NPSFM numerical attributes for suspended fine sediment and deposited sediment in freshwater environments account for some level of natural variation between different river types by utilising the New Zealand River Environment Classification (REC). The REC categorises a segment of a river within the overall river network, based on its upstream catchment area, climate, topography, and geographic characteristics (Snelder *et al.,* 2010). Using this may give greater clarity on environmental outcomes.

The below examination of the MDC and TDC regional plans exemplifies the situation for forestry under the NESPF which prevails over many existing rules in the relevant regional plans.

2.4 Proposed Marlborough Environment Plan

The Marlborough District Council (MDC) is the planning/regulatory authority that exercises the functions of both a regional and district council under the Resource Management Act (RMA) (1991) in the Marlborough District.

The MDC's resource management framework consists of the Marlborough Sounds Resource Management Plan (2011) and the Wairau/Awatere Resource Management Plan (2011). In 2016, the MDC notified a new, comprehensive Plan the proposed Marlborough Environment Plan (pMEP) to replace the multiple regulatory documents, and the decisions version of the pMEP was released in early 2020, with aspects of the pMEP subject to appeal.

In May 2018, MDC decided to retain the rules in the Marlborough Sounds Resource Management Plan (MSRMP), the Wairau/Awatere Resource Management Plan (WARMP) and the Proposed Marlborough Environment Plan (MEP), which are more stringent than the regulations in the NESPF. The retention of the rules was set to be an interim position to maintain the status quo until the rules relating to plantation forestry in the pMEP were determined.

The plantation forestry-related provisions of pMEP were developed to replace (where applicable) the provisions of the MSRMP and WARMP. Whilst still operative, the more stringent rules in these plans would apply and prevail over the NESPF. These rules related to forestry in the pMEP are therefore stricter than the operative plans.

There are rules in the pMEP that were amended or removed, and advice notes were added to align the pMEP with the NESPF. Several permitted activity standards that relate to forest harvesting are more stringent and prevail over the NESPF, while those that are not more stringent were removed from the pMEP. Standards related to the discharge of sediment to freshwater were removed (compared to the rules in the MSRMP and WARMP), as these are covered under the NESPF. However, where these standards related to Significant Wetlands or the coastal marine area, these were retained and considered more stringent under Regulation 6 of the NESPF, which allows plan rules to be more stringent than the NESPF regulations if a rule in a plan gives effect to:

National instruments

1) A rule in a plan may be more stringent than these regulations if the rule gives effect to—
    a) an objective developed to give effect to the National Policy Statement for Freshwater Management:
    b) any of policies 11, 13, 15, and 22 of the New Zealand Coastal Policy Statement 2010.

Matters of national importance

2) A rule in a plan may be more stringent than these regulations if the rule recognises and provides for the protection of—
   a) outstanding natural features and landscapes from inappropriate use and development; or
   b) significant natural areas.

Unique and sensitive environments

3) A rule in a plan may be more stringent than these regulations if the rule manages any—
   a) activities in any green, yellow, or orange zone containing separation point granite soils areas that are identified in a regional policy statement, regional plan, or district plan:
   b) activities in any geothermal area or any karst geology that are identified in a regional policy statement, regional plan, or district plan:
   c) activities conducted within 1 km upstream of the abstraction point of a drinking water supply for more than 25 people where the water take is from a water body:
   d) forestry quarrying activities conducted over a shallow water table (less than 30 m below ground level) that is above an aquifer used for a human drinking water supply.
4) The areas and geology referred to in subclause (3)(b)—
   a) may be identified in a policy statement or plan by any form of description; and
   b) include only areas and geology where the location is identified in the policy statement or plan by a map, a schedule, or a description of the area or geology.

Several of the land disturbance standards in the pMEP set out water quality standards that must be met for an activity to be considered permitted. Some are more stringent than the provisions in the NESPF while others duplicate regulations in the NESPF. To ensure alignment and no duplication (e.g., where there are no provisions under the NESPF in which stormwater discharge standards in the pMEP could be more stringent than the NESPF) the rules related to discharge of stormwater were altered so that regulations in the NESPF prevail when the discharge of stormwater to water is managed by the NESPF.
Other activities that relate to the discharge of sediment or other debris were amended so that rules in the pMEP that related to the removal of vegetation clearance, cultivation, excavation, were also allowed for the NESPF where those activities could be related to plantation forestry.

Where the pMEP is more stringent the general permitted standard applies:

[Vegetation clearance/cultivation/excavation/non-indigenous vegetation clearance] must not cause any conspicuous change in the colour or visual clarity of a flowing river after reasonable mixing, or the water in a Significant Wetland, lake or the coastal marine area, measured as follows:
   a) hue must not be changed by more than 10 points on the Munsell scale;
   b) the natural clarity must not be conspicuously changed due to sediment or sediment-laden discharge originating from the vegetation clearance site;
   c) the change in reflectance must be <50%.

The wording of the relevant rules means that the above standard would only apply to forestry activities that could affect significant wetlands and the coastal marine area and not a 'flowing river', and in matters concerning freshwater, the NESPF regulations related to sediment prevails (Regulations 26, 56, 65, 74(6) and 90 are permitted activity conditions relating to the effects of sediment discharges in receiving waters). The pMEP still included terms 'reasonable mixing' and 'conspicuous change', but numerical standards are given which arguably provide greater clarity to those activities that fall under these pMEP rules.

2.5 Tasman Resource Management Plan (TRMP)

The Tasman District Council (TDC) has equivalent powers and functions to the MDC under the (RMA) in the Tasman district.

At the time of the NESPF becoming operative the TDC made changes to the Tasman Resource Management Plan (TRMP) and referenced where the rules were more stringent than the NESPF or where the NESPF prevails over rules in the TRMP. Advice notes to this effect were inserted into the TRMP.

There are rules in the TRMP that are more stringent than the NESPF, and under Regulation 6(1) (a) or (b) of the NESPF these more stringent rules prevail over the NESPF. These relate primarily to setbacks from the coastal area, removal of indigenous vegetation, removal of vegetation, soil disturbance, and earthworks, cut and fill volumes for culverts/fords/bridges in Land Disturbance Area 2, discharges to sinkholes, discharge of sediment to a coastal waterbody, discharges of stormwater or drainage water to coastal water, or where a rule relates especially to a location, for example, Separation Point Granite Soils or the Whanganui Inlet.

Rule 36.2.2.3 in the TRMP relates especially to the 'Discharge of Sediment or Debris from Land Disturbance Activities'. The NESPF prevails over Rule 36.2.2.3 (except Rule 36.2.2.3(a)(iii)) in relation to Plantation Forestry as defined in the NESPF such that Regulations in the NESPF applies to any discharge where sediment or debris may enter water.

Where the TRMP is more stringent under Regulation 6 of the NESPF, Rule 36.2.2.3 outlines the general permitted standard for the discharge into water of sediment or debris, or water that may contain sediment or debris, from any land disturbance activity. Under this Rule land disturbance activities are a permitted activity that may be undertaken without a resource consent, if the activity complies with the following conditions:

a) *"The discharge is in such a manner that it does not cause any:*
    i. *diverting or damming of any river or stream; or*
    ii. *erosion of the bed of any river or stream; or*
    iii. *discernible change to any habitat by deposition of sediment onto the bed of any water body or coastal water body.*

Advice Note: Clause (a)(iii) where it relates to the effects of a discharge containing sediment onto the bed of a 'coastal *water body' prevails over the NES-PF because it is more stringent under Regulation 6(1)(b) NES-PF.*

b) No soil or debris is placed directly into a water body or the coastal marine area.

c) The discharge must not cause the visual clarity of the receiving water to change by more than 40 per cent as measured by a black disc at any point more than:

i. 50 metres downstream where the wetted width of the river is less than 5 metres; or

ii. 100 metres downstream where the wetted width of the river is between 5 metres and 20 metres; or

iii. 200 metres downstream where the wetted width of the river is more than 20 metres; or

iv. *100 metres from the point of discharge in the coastal marine area; measured from the furthest downstream point of the discharge*."

Like MDC's pMEP, where rules prevail over the NESPF these are primarily due to a TRMP Rule giving effect to the NZCPS and these being more stringent in relation to the coastal environment, or where a discharge is to a sinkhole as the TRMP have more stringent rules, the permitted activity criteria above would apply. As with the pMEP, the TRMP has numerical standards related to effects outside of the identified mixing zones (matters (i) to (iv) of the above rule wording). This gives greater clarity on permitted thresholds for determining compliance of activities and whether resource consent is required.

However, the types of provisions in the TRMP rule do assume that the TDC is checking the quality of water at multiple locations during rainfall events and an appropriate monitoring programme would need to be in place to record compliance.

2.6 Implementation of Regulation by Councils

Both councils, industry and central government agencies provide advice and encouragement on good practices that reduce adverse effects. However, the focus of the NESPF and the council's rules on permitted activities as a key implementation mechanism to manage adverse effects of plantation forestry means that there is a significant level of reliance on industry 'self-policing' the implementation of permitted activity requirements. Important aspects of this include the industry commitment to meeting permitted activity requirements, public visibility of practices, the ease of assessing the effects of non-compliance and the level of councils' investment in compliance monitoring and enforcement (CME) of permitted activity requirements.

Both councils have formal enforcement policies and the TDC has specific RMA charges for various forestry inspections (provided for in the NESPF). However, independent reporting on CME of the regional sector (Doole, 2020) has concluded: "*…if significant non-compliance events are occurring from permitted activity standards, then it may – in the long term- be desirable for that council to reconsider its non-regulatory approach to that activity…*" Two relevant key findings from that report were: "*There is limited codification of permitted activity monitoring across most of the sector. Cost recovery mechanisms appear influential in determining priorities*."

2.7 Summary of Regulatory Frameworks

The MDC and TDC have regional plans with rules related to activities that can discharge sediment and debris to land and water. These rules have some numerical receiving water quality standards related to the permitted threshold for determining compliance and the wording of the permitted standards provides some additional certainty over the narrative standards in the NESPF. The pMEP and TRMP rule wording give arguably greater clarity on permitted standards for plantation forestry activities in the coastal marine area, regionally significant wetlands, or at specific locations identified in the TRMP or pMEP. In these circumstances, the TRMP and pMEP are more stringent and therefore prevail under Regulation 6 of the NESPF. In both regions, foresters working near the coast will likely require consent under the relevant regional plan for discharges to the coastal environment, regionally significant wetland, or a specific location. However, they also will require consent under the NESPF for discharges of sediment to freshwater and the marine environment where conspicuous changes in the colour or clarity of water occur beyond the zone of reasonable mixing. In both scenarios, monitoring and assessment of the state of the environment would be required. This will result in forestry operators needing to comply with two sets of permitted standards for discharges of sediment and organic debris.

3. ENVIRONMENTAL EFFECTS ON MARINE AND FRESHWATER

Catchment management relies on the understanding that land and water are connected through several dynamic processes. Forestry activities are widely acknowledged internationally to affect stream water quantity and quality (e.g., Chang, 2006; Buttle, 2011) by altering the hydrological and biogeochemical processes that occur within catchments. In New Zealand, forestry also is a recognised land use activity that can result in changes to hydrological and biogeochemical processes (Neary *et al.*, 1978; O'Loughlin *et al.*, 1984; Fahey, 1994; Fahey & Jackson, 1997; Adams & Fowler, 2006). In New Zealand in particular, given the high value placed on natural resources, land disturbance effects from forestry activities have been studied (Fahey & Jackson, 1997; Quinn *et al.*, 1997; Glade, 2003; Clapcott *et al.*, 2011). Johnston *et al.,* (1981) raised concerns of increased soil erosion resulting in deposition of fine-grained sediments and tree detritus in the Marlborough Sounds. Increased erosion was signalled to potentially decrease the existing high-water quality in the sounds and threaten marine life and farming, fishing, and the aesthetic qualities of the Sounds (Fransen *et al.,* 1998). Consequently, land disturbance is closely monitored, primarily via suspended sediment and turbidity or water clarity measures, that are used as proxies for assessing impacts on freshwater and marine environments, but also the impact on downstream users and continued stability of the land.

Mature trees are effective on steep land for limiting erosion in New Zealand (e.g., Ekanayake *et al.,* 1997; Marden, 2018). In terms of forestry, mature plantation forest tree roots reduce erosion on hillslopes by increasing soil strength and slope stability. However, during and after clearance of plantation forests, root systems are damaged, and soil is significantly disturbed. Land vulnerability and how significant the loss of soil is due to erosion depends on the characteristics of the environment and determines the 'window of vulnerability' for large scale events occurring (Marden & Rowan, 2015). The conditions that predispose an environment to erosion include 'mechanical facets', including soil type, surface land cover, and slope, and those that are hydrological including water balance and soil permeability, and climate (Amishev *et al.,* 2014). Duration and frequency of intense rainfall events are key factors that trigger mass-movement and gully erosion in steepland plantation forests (Satchell, 2018). The saturated conditions these large heavy rainfall events cause increases the risk of slope failure (Bloomberg*,* 2011).

Forest clearance activities expose large areas of bare ground to the erosional effects of rain, surface runoff, and wind, causing a high level of disturbance and increases in stream suspended sediment yield (Woodward & Foster, 1997; Chang, 2006; Croke & Hairsine, 2006; Basher *et al.*, 2011). This can result in compaction, rapid runoff, and increased risk of landslides and other erosion processes (Croke & Hairsine, 2006). Specifically, at and after the forest harvesting stage, sediment in stormwater run-off from roads and skid sites entering waterways is a quick point-source of sediment in the disturbed landscape. Vehicles and machinery crossing waterways without a properly formed culvert, ford or bridge can also create a lot of sediment in waterways and damage the stream bed. More generally, landslips from post-harvested land can generate large quantities of sediment and debris as a result of severe rainfall events and deliver this into streams, even in forested settings (Marden & Rowan, 2015; O'Loughlin, 2005).

If harvest residues are left either in the waterway and/or floodplain or left on slopes susceptible to mass movement, landslide-generated sediment when mixed with this woody debris can form a debris flow and if confined to a channel, debris flows can be highly destructive (Scion, 2017; Visser, 2018). Shallow landslides can transform into debris flows and deliver large quantities of sediment, boulders, and woody debris further down the catchment (O'Loughlin, 2005). Debris flows erode ephemeral gullies and riparian margins because of the large volume of sediment and debris carried (Phillips *et al.,* 2017) and occur where slopes are steep and susceptible to mass failure (Scion, 2017). Debris flows that entrain cut-over harvest residues are infrequent but are high-risk events. Negative consequences downstream include debris dams, accumulation of material along coastlines or in lakes channel erosion and scour, deposition of sediment and aggradation.

Sheet and rill erosion resulting from earthworks, harvesting and land preparation can result in loss of soil and generation of sediment (Bloomberg, 2011). Surface erosion, although a relatively minor contributor of sediment into water channels compared with gullying and landslides (Marden & Rowan, 2015; Marden *et al.,* 2007), can transport large loads of sediment down-slope and is a significant contributor of sediment to streams and the coastal environment (Marden & Rowan, 1997; Marden *et al.*, 2002; Marden *et al*. 2007). This accelerated erosion is recognised in streams as increased suspended sediment yield and is used to understand catchment-wide effects as a tracer for land disturbance (Croke & Hairsine, 2006).

In the Marlborough Sounds, sediment generation and risk of sedimentation are enhanced by forestry activities occurring on a weathered lithology, with steep topography, in exposed areas subject to high-intensity rainfall (Laffan *et al.,* 1985). In the Tasman Region steep highly erodible Separation Point Granite geology predisposes forested landscapes to the risk of instability, including the influence of infrequent high return period storms (Basher & Hicks, 2002; Clapp, 2009; Basher *et al.,* 2011). Therefore, in these regions, landslips, and sheet and rill erosion are common sediment mobilising mechanisms resulting in increased sediment delivery to coastal and freshwater resources (Urlich, 2015). Furthermore, floods and debris flows carry great potential for damage to infrastructure and environmental values. Past episodes of mass movements from high-intensity rainfall events have shown the potential for damage is significant (e.g., Abbott, 2006; Dymond *et al.,* 2006; Phillips *et al.,* 2012). In the face of recent and increased media coverage of these types of events (for example Ligar Bay 2011, Marlborough Sounds 2014, Tolaga Bay 2018, and the Otuwhero River 2018) there appear to be public expectations that the forestry industry and regulatory authorities will better manage forestry activities occurring in these landscapes.

Sediment generation and debris flows are the consequence of mass movement and/or surface erosion and are connected to the fluvial system via hydrological flow paths. Hydrological flow paths direct eroded material to receiving water bodies, where it is either held in temporary storage in the channel, mobilised and transported downstream, or deposited at the river mouth into a final receiving body (lakes, estuaries, or the coastal margin). Excess sediment in freshwater and marine environments reduces the growth of plants, damages fish gills, and can smother riverbed and seabed ecosystems. The effects on receiving environments of these forestry-related mass movement and sedimentation processes are well documented in New Zealand, most recent reviews or studies include examples from North Canterbury (Baillie & Rolando, 2015), Manawatu (Abbott, 2006, Basher 2013), Motueka (Basher *et al.,* 2011), and the Marlborough Sounds, (Urlich, 2015; Urlich & Handley, 2020). The effects of debris flows are also well documented but appear more readily in media reports than from literature sources, because of the often-damaging consequences of debris flows on property and the built environment, and the natural environment.

This assessment has not included an analysis of the effectiveness of the NESPF, as that goes beyond the scope of this report. Once the NESPF has been in effect for long enough to show conclusive effects, it would be valuable to make this assessment of the NESPF's effectiveness. Table 1 below summarises key environmental effects from deposited sediment, fine sediment, and debris flows on the natural environment.

Table 1: Summary of environmental effects of sediment and debris flows on freshwater and marine environments. (Sources: Ryan (1991); Gillespie (2007); Bilotta and Brazier (2008); Geertsema *et al.* (2009); Davies Colley *et al.* (2015); Visser and Harvey (2020); Urlich (2015, 2020).

	Deposited Fine Sediment	Suspended Sediment	Debris Flows
Marine Environment Coastal/Estuary/ Lagoons	Smother benthic habitats and thereby change ecological composition by killing and displacing macrofauna. Seagrass reduced in extent and fine sediment coating on the leaves. Effects of changing sediment fluxes are frequently observed at the coast, as excessive loading of riverine sediment can cause smothering of estuaries and the seafloor and can cause beach erosion or aggradation. Fine sediments on the relatively flat seabed surface can be readily resuspended by tidal and wave-generated currents to the extent that they interfere with the growth/survival of suspension-feeding shellfish.	Increase turbidity and reduce light transmission in the water column and thereby affect photosynthesis; change biogeochemical gradients and cause negative effects to benthic microalgae; clog fish gills and the feeding parts of sediment-dwelling filter-feeders, and cause chronic effects on macrofauna physiological condition and behaviour. Excess fine sediment in the nearshore zones is a natural hazard and can silt up harbours and estuaries affecting shipping and navigation.	Debris flows deposit material at the coast typically in fans. Boulders and logs deposited in washouts and flooding. Forestry waste and slash washing up on beaches and log debris clogging river outflows to coast. Sediment-laden plumes can extend over large areas of coastline. Very fine-grained sediments can be carried tens of kilometres, or much further, offshore and transported along the coast by wave action and tidal currents. Foreshore and seafloor smothering with logs and forestry slash, mud and silt.
Freshwater Rivers/Lakes/ Wetlands	Deposited sediment affects the substrate composition of a waterway and therefore changes the coverage of fines and bed stability. Deposited sediment provides a readily available in-stream source of sediment that can have flow-on effects downstream. Fine deposited sediment has a complex relationship with periphyton and macrophytes. Affects fish habitat and food supply. Increased drift and decreased abundance of benthic invertebrates. In lakes, deposit sediment causes benthic smothering, sediment resuspensions and alteration to sediment oxygen demand.	Deposits sediment into a stream or pollutes a drinking water source with sediment and fine organic debris. Clogging riverbed sediments and reducing habitat function. Reduce light transmission in the water column and thereby affect light penetration, suspended sediment concentration, the visual clarity, and sediment budget of a waterway. In lakes light transmission, oxygen demand, conveyance of sorbed contaminants is affected by sediment concentration, visual clarity and photosynthesis, depth limit for benthic plants, foraging efficiency, food quality.	Exacerbate flood hazard and potentially cause severe impacts for downstream infrastructure and communities. Debris flows have a very high sediment concentration by weight and are more powerful and destructive than water alone and may carry woody material and boulders. Damage to river channels by filling and/or eroding the stream channel for great distances. Capable of relocating and depositing large amounts of material from the slopes to the valley bottoms. Dam streams and rivers impacting both water quality and fish habitat.

3.1 Case Studies

The following sections describe the values of the natural and associated built environment for six areas in the Marlborough and Tasman districts (Figure 1). These case study areas were selected given the existing knowledge of how forestry activities have affected certain aspects of the natural and built environments. The purpose of presenting these case studies is to highlight the complexities of the types of environments where forestry activities are occurring, and summarise the historic effects experienced. This should help inform the development of tools for mitigating these effects in the future.

The following sections present details relating to:

- The catchment location, and catchment characteristics, including land use and land cover, plus any historical changes, other socio-economic values within catchments.
- Description of primary way ways and/or coastal areas including values, water quality classifications, and high-value environments, include those with value to Maori.
- Where relevant, the documented threats and in particular impact of debris and sediment.

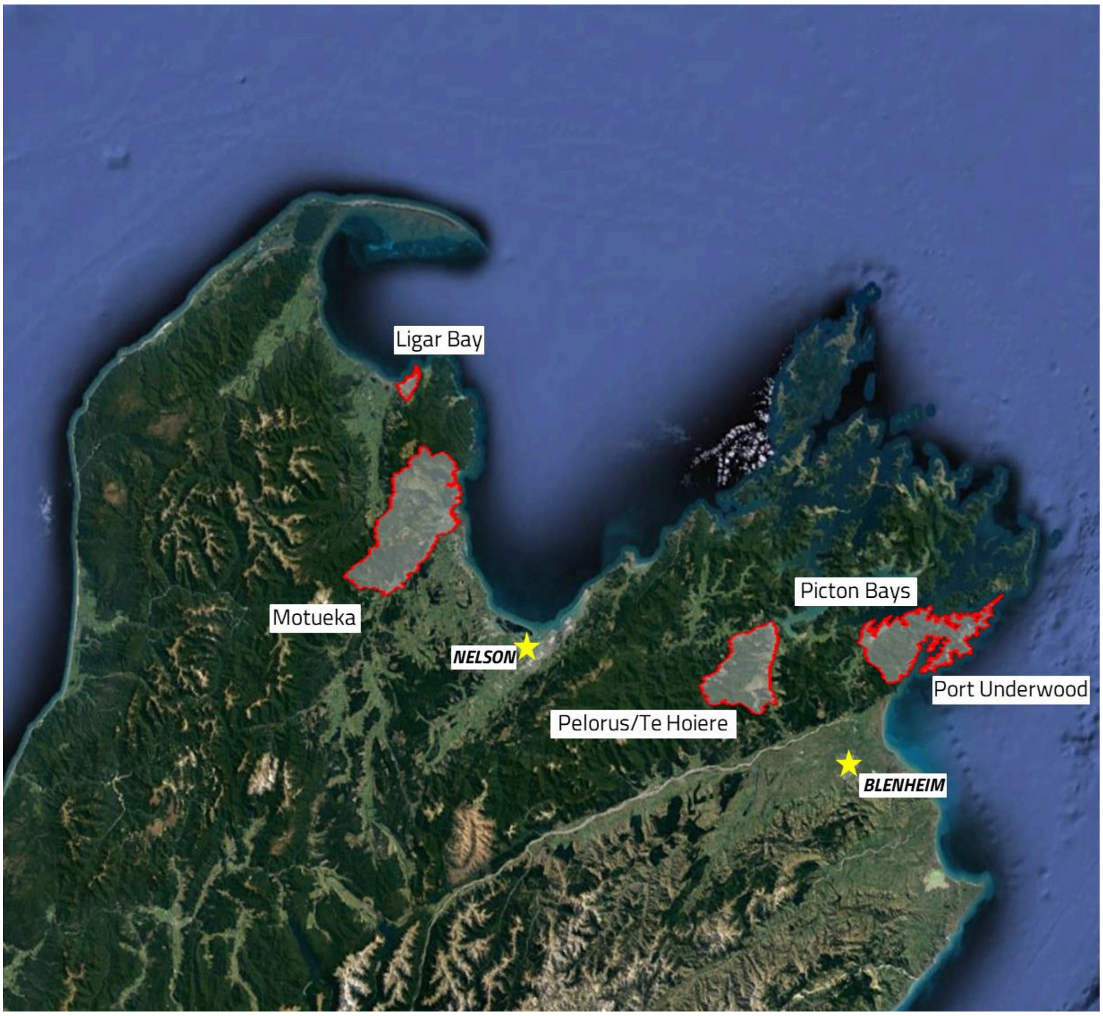

Figure 1: Location of case study areas across Marlborough and Tasman Districts.

3.1.1 Picton Bays

Overview

Picton Harbour, Waikawa Bay and Shakespeare Bay, known collectively as the Picton Bays, are the gateway to the Marlborough Sounds and are used recreationally and commercially by thousands of people every day. Forestry has been evident within this location for many decades with the first trees planted in the early 1930s, following a drop in sheep and dairy farming prices. The topography is dominated by abrupt transitions from valley floors to steep slopes, with both Picton and Waikawa being located on flat topography. Shakespeare Bay is the easternmost bay and contains a small collection of personal boats and is also the location of Waimahara Wharf which is a 200m-long multipurpose wharf that is predominantly used for log export operations.

The Picton and Waikawa environments are dominated by existing built infrastructure. Picton is home to the main ferry thoroughfare from the South to the North Island. The township is dominated by port activities and forestry through both harvesting in the local area and the export of logs. The Waikawa Marina recently received resource consent to extend the marina by 252 berths, to reduce the demand for berths at Picton and the existing marina at Waikawa. The physical environment is well known for its recreational value, with an abundance of walking and mountain biking tracks along the Kanuka Trial that extends from Picton Road to Snout Peninsula. Also, the site holds strong cultural significance with the location of the local Iwi's Marae within Waikawa. The character of the environment is identified as being a combination of both the built and natural environment, and these are highly valued by residents.

Another concern about further risk from forestry-related activities is the highly valued built environment that borders the forested environment. Concerns have included the large number of trucks hauling logs and the effects of landslides. Landslides could have infrastructural, economic, and social impacts on residents who reside there, but also on the tourist/goods distribution flows associated with the Port of Picton.

Coastal Environment

The coastline is dominated by dense vegetation from the base of the Picton Marina to the Snout Peninsula. Natural marine ecosystem communities within the Picton Bays are similar to those in much of the Queen Charlotte Sound, with only the estuarine areas, and possibly the tubeworm beds at Bob's Bay being of special interest (Newcombe & Johnston, 2016).

The most severe damage to marine environmental health in Picton Bays may have been the historical input of sediment-associated with European settlement, which has reduced seabed habitat integrity (Newcombe & Johnston, 2016). Disturbance of the seabed from continuous inputs of sediment and regular port activities maintains fine terrestrial sediments at the surface of the seabed and accordingly exacerbates the impacts of sediment input. The increases in sediment deposited into the coastal environment could also have a direct flow-on effect on the depth of the channels for vessel passage.

Iwi have expressed concern over the increase in sediment deposition into the Picton Bay following a slip event in 1990 from roading, which caused the movement of an estimated 400m^3 of sediment (Newcombie & Johnston, 2016). The effects of sediment have proven to be more intrusive within this location as the bay is subject to limited tidal movements (Newcombie & Johnston, 2016). The sediment also provides a greater risk to native fauna within the coastal environment, for example, sediment dislodges shellfish such as paua making them vulnerable to predators (MfE, 2019).

Waterways

The primary waterways within the case study location are the Waitohi River (REC - CW/L/HS) and the Waikawa Stream (REC - CW/L/HS) that drain to Picton and Waikawa Bays, respectively. The Waitohi River and Waikawa Streams have a special status in the rohe of Te Ātiawa and have had a close association with Waikawa Marae in Tōtaranui / Queen Charlotte Sound (Te Atiawa & MDC, 2018). The Waitohi River and Waikawa Stream have relatively small catchments, which is typical of the Marlborough Sounds. There are small areas of production forestry and extensively grazed pasture in both catchments. The influence of these on water quality cannot be assumed to be minor (Te Atiawa & MDC, 2018). Several smaller tributaries drain directly into the bay areas.

Land Air Water Aotearoa (LAWA) is a national database that connects people with New Zealand's environmental monitoring data, enabling communities to access information relating to the different pressures and conditions on freshwater resources. The state of water quality presented on the LAWA website compares the median of monitoring results for the last five years at a specific site with other sites around the country. The median for a site can be compared to all other sites with similar land use and altitude. The data used to calculate trends are the same as used for the regional state. LAWA displays regional trends for the last five to ten years which helps to identify whether a site has improved, degraded, or stayed the same. The state of water quality is assessed against the objectives within the National Policy Statement for Freshwater Management (NPS-FM; New Zealand Government 2014) and the trigger values for physical and chemical stressors in New Zealand rivers from the ANZECC guidelines (ANZECC, 2000).

LAWA reports 5-year median turbidity for the Waitohi River of 0.91 NTU. Based on the REC for this river, the waterway would be categorised under Class 3 for suspended fine sediment (NPSFM, 2020). Using an established turbidity-visual clarity rating for New Zealand rivers (see Franklin *et al.,* 2020), a median 0.91 NTU coverts to a visual clarity of 3.6m and therefore would be classed Band A under the NPSFM and meet the standard for suspended fine sediment.

The water quality of the Waitohi River is likely to be representative of similar catchments draining to the Picton and Waikawa Bays that originate in native bush, with some areas of forestry and urban activities. However, there are pockets of forestry that when harvested could cause sediment discharges that temporally cause reductions in visual clarity and affect the long-term median and status under the NOF; the current A band status represents the minimal impact of suspended sediment on instream biota and ecological communities are like those observed in natural reference conditions). A reduction in visual clarity to anything less than 2.95m would start having low to moderate impacts.

3.1.2 Te Whanganui/Port Underwood

Overview

Te Whanganui/Port Underwood is located on the easternmost point of the Marlborough Sounds and has a selection of smaller and larger bays. The area is characterized for having a low population density as it is isolated from major townships and is known for relative remoteness, with less land-based development than in the more sheltered inner bays of the Marlborough Sounds. This remoteness contributes to the rural feel of the landscape and sense of naturalness. If a forestry debris flow or landslide was to occur in this location, it could isolate small communities as there is a single road entry/exit point into Port Underwood/Whataroa Peninsula.

Parts of the Port Underwood landscape are designated as Outstanding Natural Landscape in the relevant RMA plans because of the exceptional biophysical and associated landscape values and very high landscape values. The environment is dominated by dense native and exotic forestry on steep infertile slopes. These slopes are not suited for productive farming or viticulture which are dominant productive land uses in the existing Marlborough region. The combination of the limited built environment and steep slopes makes it better suited for forestry. The landscape retains large amounts of indigenous vegetative cover, notably on its upper slopes, which form part of the broader Robertson Range. At lower elevations, a greater level of modification occurs, particularly around and following the Port Underwood Road, where tracks, power lines, buildings, pasture, commercial forestry, and foreshore infrastructure are present.

The Port Underwood contains rich historical and cultural associations for both Māori and Europeans. The area is valued for the former whaling communities once established, including at Ocean Bay. Furthermore, at Oyster Bay a marker commemorates the signing of the Treaty of Waitangi that took place in 1840 on Horahora Kakahu Island, and a tree found upon the island has been specified as a Category II Heritage Resource in the Marlborough Regional Plan, while Pukatea/Whites Bay is the location of the first telegraphic link to the North Island in 1866. Pa sites and other archaeological evidence of early Māori settlement line the coast of Port Underwood.

The area is also valued for its main economic activities being mussel farming with an estimated 200 hectares of farms across the Port Underwood Peninsula with the second-largest sector being plantation forestry. There are also a large number of domestic holiday homes and small permanent communities. Small coves and bays occur frequently on the coastline, where numerous small fishing and former whaling communities established, including at Ocean Bay. These bays contain rich historical and cultural associations for both Māori and Europeans. At Oyster Bay for example, a marker commemorates the signing of the Treaty of Waitangi on nearby Horahora Kakahu Island, and a tree found upon the island has been specified as a Category II Heritage Resource in the Marlborough Regional Plan, while Pukatea/Whites Bay is the location of the first telegraphic link to the North Island in 1866.

Marine Environment

Some bottom trawling extends into Port Underwood and aquaculture is a significant feature around the central peninsula and along the eastern side of the Port Underwood. The Port Underwood marine ecosystem has been identified as being nationally important because it contains a large number of juvenile crayfish and oystercatcher. Between Robertson Point to Pipi Bay macroalgae are growing on soft sediment ranging from 75-95% cover (Davidson *et al.,* 2020). Marine farms and forestry harvesting are the main threats to marine biodiversity (Davidson *et al.,* 2020). There are conspicuous brown seaweed communities, offshore red algae beds, and massive tubeworm colonies in places (Davidson *et al.,* 2020). The Port Underwood marine environment is mostly sheltered, often turbid with shallow waters, and has extensive mud bottoms with narrow rock/cobble fringes. Various seabird and marine mammal species utilise these waters. Of note are Hector's dolphins which visit the area from neighbouring Cloudy Bay.

The Knobby's is an area that lies 3.5km from Ngakuta Bay, 6km seaside of Port Underwood. The area's tubeworm mounds have been identified as very sensitive to anthropogenic effects, and the reef supports macroalgae beds that contain native and introduced species (Davidson *et al.,* 2020). The main threat is sediment smothering during/following forestry harvesting, and this threat can last up to 5-8 years following harvest (Davidson *et al.,* 2020).

In February 2018, seven major slope failures were triggered by rainstorms during Cyclone Gita (Boam, 2018; Urlich, 2020). This resulted in the deposition of sediment, slash and debris flows into the coastal waters of the Port Underwood. Future events of similar magnitude pose the same risks.

Waterways

The primary waterways within the case study location are small, short low order catchments draining the gullies that discharge into the bays of the Port Underwood. Therefore, runoff in the area can be characterised as locally concentrated, as it is channelled into steep gullies with a direct connection to the coastal environment.

These short, low order catchments primarily have a REC classification of CW/L/HS. There is no LAWA data for waterways within the Port Underwood. The REC classification makes most of the waterways of the Port Underwood drainage network Class 3 for suspended fine sediment, and therefore a national bottom line for suspended sediment concentration of visual clarity <2.22m at which point there is a high impact of suspended sediment on instream biota and ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

Using the established turbidity-visual clarity rating for New Zealand rivers (see Franklin *et al.,* 2020), annual median turbidity of 1.77 NTU would need to be maintained to remain in-line with suspended fine sediment limits. However, at a visual clarity of 2.22-2.95m there is a low to moderate effect of suspended fine sediment likely to occur in these waterways of the Port Underwood, and forestry activities likely play a role in elevated suspended sediment concentrations in freshwater.

3.1.3 Pelorus/Te Hoiere

Overview

The Pelorus River Catchment is made up of several smaller tributaries and begins in the upper reaches of the Richmond Ranges. The catchment area is 1,149km^2 and is approximately 40 km in length to where it exits in Kaikumera Bay/ Havelock Estuary and the Pelorus Sounds. Historically, the Pelorus Catchment was dominated by indigenous forests which are still the dominant land use within the upper catchment (Coutts & Urlich, 2020). Exotic forests and harvested forests make up a large proportion of hill country and steepland in the mid-catchment. Land use in the lower catchment is dominated by pasture and dairy farms (Henkel, 2019).

Havelock is the main town in the Pelorus catchment. It has become a popular tourist destination as the gateway to the Pelorus Sounds, with activities like kayaking, jet boating and cruises. Havelock has a large 340-berth marina for private and public vessels and is also the base location for Sanford Fisheries which serves some of the marine farms in the area.

The Pelorus River and Kaikumera Bay/ Havelock Estuary is located close to Cullen Point Scenic Reserve and Mahakipawa Hill Scenic Reserve with many coastal walking tracks and connects to the Queen Charlotte Track. The Pelorus River at Pelorus Bridge is one of the most popular river swimming sites in the Marlborough region with a campground, and café with shops located nearby. There are also several easy walks at Pelorus Bridge that provide an opportunity to explore the surrounding native bush and enjoy river views.

The Pelorus River has strong cultural connections with local iwi. Ngati Kuia used the river to collect kaimoana, tuna and seabirds. Europeans settled in the catchment following the discovery of gold in 1864. Shellfish including mussels: the green-lipped mussel (Perna canaliculus) the blue mussel (Mytilus galloprovincialis), fan mussel (Pinnidae), and the horse mussel (Atrina zelandica) were an important component of the diet of Māori (Handley & Brown, 2012). Havelock and the Pelorus Sounds are now the main source of green-lipped mussels within NZ and are a significant economic contributor to the region.

The river catchment has been identified as being one of 14 priority catchments acknowledged by the Department of Conservation's Te Awa Program, which is a bottom-up collaborative strategy to improve the health of the Pelorus River and estuary. There is now a multi-million project to restore water quality in the Pelorus catchment (Ranford, 2020) which could cost $75 million over 10 years to deal with the high levels of sediment, nitrogen, and *E. coli*. The estuary has been identified as having a high to very high risk of adverse ecological effects if not mitigated or addressed (Ranford, 2020). The project has been allocated eight million dollars through the Department of Conservation's Te Awa programme and is a collaborative initiative between iwi, local and central government that will include setting aside 13.5 hectares for wetland restoration and native plant nursery. The Kotahitanga mō te Taiao Alliance is undertaking the Te Hoiere/ Pelorus River pilot project and are working toward achieving specific environmental, social, cultural, and economic goals.

Marine Environment

The Havelock Estuary is valued for its aesthetic appeal, high biodiversity, scientific appeal, recreational activities, shellfish collection (Henkle, 2019). The Havelock Estuary has been identified by MDC as a priority for understanding the sources of and effects of sediment, given its size and high ecological and human value that are vulnerable to sedimentation and habitat loss (Henkel, 2019).

In the lower catchment, estuary margins and wetlands are home to a selection of wetland birds, for example, the banded rail, fernbird and are the wintering site of black-billed gulls, which have all been threatened due to an increase in sediment and changing land use.

Sedimentation in the Estuary is an acknowledged issue, with sediment deposition derived from the surrounding land reflecting the change in land use that has been occurring in the catchment over the last century (Coutts & Urlich, 2020). Forestry contributes to the sedimentation in the Havelock Estuary and Pelorus Sound. In Pelorus Sound/Te Hoiere, annual sediment accumulation rates have increased five to 20 times since the 1860s (Handley *et al.,* 2017), and the accumulation of sediment is not restricted to the inner Estuary only, and sediment in the outer Pelorus Sounds derive from sediment sources from the Pelorus river catchment. Sediment source tracing work completed by NIWA identified that sediment transported from forestry represents 2 cm of the seabed within the Pelorus Sounds some 40-50km from the Havelock Estuary and can also be derived from local harvesting in the outer sounds (Handley *et al.,* 2017). This potential for sediment relocation from the Estuary to outer sounds is possible with the complex hydrodynamics associated with the large freshwater inflow at the head of the Pelorus Sound and saline oceanic bottom water intrusions into the Sound (Handley *et al.,* 2017). Therefore, this is a major factor in deciding where and when management interventions including improved land-use controls, particularly for forestry, in the Pelorus and Kaituna River catchments, are required to mitigate further degradation effect from sediment inputs.

Waterways

The Pelorus, Rai, Wakamarina, and Kaituna rivers dominate the river network within the Pelorus Catchment. The upper catchment slopes are steep and periodically receive intense rainfall events, with severe flooding in the Pelorus, Rai, Wakamarina Rivers. The Pelorus River contains 14 native freshwater fish species with nine of these being threatened or at risk of extinction and is therefore a highly valued freshwater resource. Ngati Kuia are the Tangata Whenua of Te Hoiere and are also one of the oldest iwi in the Te Tau Ihu rohe. The Kaituna and Pelorus/Te Hoiere have a special status in the rohe of Te Tau Ihu and have had a close association with the Kaituna and Pelorus/Te Hoiere to gather and provide food, especially kaimoana, tuna and seabirds (Coutts & Urlich, 2020). There is a significant influence of European settlement in the catchment, including production forestry and extensively grazed pastures.

From the LAWA website and reported data, the lower Te Hoiere/Pelorus River is currently classed as 'Good', however, water quality for a number of its sub-catchments, including the Rai/Ronga and the Kaituna catchment is classed as 'fair' with rapid water quality declines over relatively short distances downstream.

The primary waterways within the case study location are classified in the New Zealand REC at their relevant LAWA water quality monitoring sites as follows, with 5-year median turbidity for the sites reported by LAWA:

- Pelorus at Fisherman's Flat has a REC classification of CW/H/HS and 5-year median turbidity of 0.69 NTU
- Rai River at Rai Falls has a REC classification of CX/L/HS and 5-year median turbidity of 0.81 NTU
- Wakamarina at the State Highway has a REC classification of CX/H/HS and 5-year median turbidity of 0.40 NTU.

There is no LAWA site for the Kaituna River.

Based on the REC for these rivers, all three waterways would be categorised under Class 3 for suspended fine sediment (NPSFM, 2020). Using an established turbidity-visual clarity rating for New Zealand rivers (see Franklin *et al.,* 2020), the relevant 5-year median visual clarity for each river is:

- Pelorus at Fisherman's Flat 0.69NTU = 4.38m
- Rai River at Rai Falls 0.81 NTU = 3.90m
- Wakamarina at the State Highway 0.40 NTU = 6.49m

Given the high visual clarity of the rivers, these are classed Band A under the NPSFM and currently meet the standard for suspended fine sediment. This suggests the visual clarity of these rivers are very good over the 5-year median period, however at times there are distinct periods in the available data record (as reported on the LAWA website) where turbidity increases likely in response to flood events, and likely represent the distinct pulses of suspended sediment that are contributing to the reported increases in sediment yields in the Havelock Estuary. The A band status represents a minimal impact of suspended sediment on instream biota and ecological communities are like those observed in natural reference conditions. However, distinct pulses of sediment that produce high turbidity levels likely have short-lived effects on instream biota. As evidenced in Handley *et al.* (2017) forestry activities contribute to these higher sediment yields at times, and therefore, forestry activities in the Pelorus Catchment may contribute to periods when suspended sediment standards for these main rivers cannot be met.

3.1.4 Otuwhero Inlet

Overview

Otuwhero Inlet including the small township of Marahau is a popular tourist destination on the western coastline of Tasman Bay, just south of the Abel Tasman National Park. Otuwhero Estuary valley floor is dominated by farms (pasture) with several roads and tracks. The hillsides are covered by a combination of commercial forestry, pasture, and regenerating scrub.

The catchment is characterised by Separation Point Granite geology, which is easily erodible and well-reported as a factor contributing to the severity of landslide/debris flows wherever it occurs. Landslides and debris flows have historically caused extensive damage to salt marsh habitats in several locations along the Inlet, raising estuaries and result in the permanent loss of this habitat (Davidson, 2018). This has altered the natural character of the area.

A range of socio-economic effects have historically resulted from storm-initiated forestry landslides and debris flows in the Otuwhero catchment. For example, a significant landslide event 15-17 June 2013 was the fourth storm that caused landslides and debris flows in three years resulted in a landslide that destroyed a home in Otuwhero Inlet and resulted in the fatality, with other houses displaced (Page, 2013). These homes were built on the remains of former landslides, where the hazard from landslides was too high for housing. During storms in 2013 and 2018, landslides occurred in a logging area in Shaggery Forest and debris flows, and landslides blocked several roads between Marahau and Kaiteriteri, alongside the Motueka River. Griffiths *et al.* (2020) reported that over 4,500 landslides occurred in the Nelson-Tasman region during Cyclone Gita in 2018.

Marine Environment

The Otuwhero Inlet catchment contains elements of human settlement, forestry blocks, land clearance and agricultural pastures. The result is water-logged mud and sediment that has been transported from the Marahau and Otuwhero Rivers into the Otuwhero Inlet, causing ecological impacts. For example, following Cyclone Gita the margins of Otuwhero Inlet, adjacent slips had deposited sediment into upper tidal areas completely smothering salt marsh habitat at several locations. Where this has raised the estuary above the maximum tidal limit for salt marsh and herb field species, exotic grasses will now grow and represents a permanent loss of salt marsh habitat (Davidson, 2018).

Generally, across the estuary, coarse substratum has been smothered by a layer of mud, while salt marsh and herb field habitats have been smothered and species assemblages altered (Davidson, 2018). The smothering of estuarine vegetation in these ecologically important estuaries contravenes the NZCPS.

Coastal inundation and on-going coastal erosion of the foreshore are risks for settlements and roading networks. Much of the land in low-lying Marahau is covered by a Cultural Heritage Precinct overlay, with multiple archaeological sites located within the precinct. A defended pa site that consists of terraces and a platform on top of the bluff above the sand spit holds cultural significance for local iwi. There is also significant natural character value for the land around Marahau.

Waterways

There are minimal infrastructural services in the Otuwhero Inlet and a small permanent community in the nearest township of Marahau. Kaiteriteri is a seaside resort town that resides south of the estuary and is home to the highest proportion of holiday homes in Tasman, as tourist numbers in the summer months almost triple the population. Many of these communities are supported by private water supplies, as there is no council reticulated system. Many operate rainwater storage systems, although there are also some surface water takes. Therefore, for the parts of the Marahau Valley that are low-lying and flood-prone from tributary streams, water supplies and wastewater systems are highly susceptible to damage from sediment and forestry debris.

Following the aftermath of Cyclone Gita, locals called for the control or even cessation of forestry around Marahau (Otuwhero Inlet) (Neal, 2018). This highlights the potential social-economic and human values associated with the area, as well as the ecological values of the inlet that are highly susceptible to damage from forestry activities occurring in the Otuwhero Catchment.

There is no LAWA monitoring site in the Otuwhero River catchment. There is no nearby LAWA monitoring site with similar characteristics in which to identify a representative site for comparison.

At the confluence of the river with the estuary, the New Zealand REC classification (CW/H/P) means the river would be categorised as Class 1 under the NPSFM 2020 for suspended fine sediment. The national bottom line standard for suspended fine sediment is 1.34 m and therefore a turbidity of 3.57 would apply when using the equation of Franklin *et al.* (2020) to convert visual clarity to turbidity. It is likely given the reported sedimentation occurring in the estuary that a 5-year turbidity or visual clarity median would breach this standard, and therefore, forestry activities are unlikely to demonstrate compliance with suspended sediment standards under the NPSFM 2020 without significant mitigations in place to ensure there is no change or effect to the Otuwhero River and Estuary.

3.1.5 Motueka River – Shaggery Road

Overview

Shaggery Road lies on the outskirts of Kahurangi National Park and is a local road that leads to plantation forestry land. There are several private dwellings located on Shaggery Road. The character of the landscape is predominantly rural with a mix of forestry and sheep and beef farming. Horticulture and dairy farming are small but increasing slowly in the lower flatter areas at the bottom of the catchment. The landscape also contains a large proportion of indigenous forests, especially in the upper reaches of the river catchment.

The Motueka River lies south of the Shaggery Road. The Motueka River is fed by seven main tributaries which do not run through any major townships. One of these tributaries is Shaggery Creek a short, steep catchment draining basement rocks and granite.

Following an intense rainfall event in 2013, the Shaggery catchment was hard hit by landslides, as documented by Page (2013). The landslides deposited sediment and woody debris into rivers and onto local roads in the area. Debris that accumulated eventually caused damage and the loss of the bridge across the Shaggery River (Page, 2013). Residents were cut off for three days while repairs were being made to the bridge (Page, 2013). Of the landslides that occurred, 47% were associated with access roads to the forestry blocks (Page 2013).

In comparison, Cyclone Gita in 2018 also generated an intense rainfall event and landslides occurred across the Tasman Region, as also documented in previous case studies (Griffiths *et al.,* 2020). Media reports highlighted the intensity of the rainfall event associated with Cyclone Gita in the Shaggery Road area. Shaggery Creek became a torrent with debris and picked up and carried off four vehicles and destroyed one home as reported by Sivignon (2018). Silt and debris were deposited across a wide area and increased the level of the land by over 1 meter in some locations (Sivignon, 2018). As with the Otuwhero Inlet, the community in the Shaggery catchment believe that forest harvesting was to blame. This highlights the potential social-economic, human, and asset values associated with the area, as well as the ecological values of the Motueka River and its cultural importance. As evidenced by historical and recent storms, the area around Shaggery Road is highly susceptible to damage from forest harvesting activities occurring in the Shaggery Catchment, especially on the highly erodible Separation Point Granites.

Waterways

The Motueka River is well known for its kayaking, fishing (brown and sea-run trout), walking and wine tasting and also boarders the Kahurangi National Park, which has the Heaphy Track. The Motueka River runs in parallel but not directly within the national park.

By national standards, the Motueka River water quality is relatively good, however, excessive fine sediment discharges and high summer water temperature in many tributaries are probably the biggest pressures on water quality (James & McCallum, 2015). However, any increases in sediment concentrations are often associated with forestry harvesting activities.

A Water Conservation Order exists for the Motueka River. Gazetted in 2004, this order details the catchment areas covered and the restrictions placed on activities. This Conservation Order requires fish passage to be maintained and generally restricts the granting of resource consents for activities that would exceed water quality standards such as turbidity by protecting trout angling and blue duck values, as well as recreation and wild and scenic values. The Motueka River is known for its recreational trout fishery and drains to the Motueka River Estuary, which has significant ecological values including major salt marshes with glasswort, jointed wire rush, and sea rush species dominant. Infrastructural assets including stopbanks have been installed in the Lower Motueka River, primarily to protect Motueka township and surrounding infrastructure.

There is no LAWA data specific for the Shaggery Creek, however the wider Motueka and other key tributaries are monitored.

At the confluence of Shaggery Creek with Motueka Creek, the New Zealand REC classification (CW/L/Pl) means the river would be categorised as Class 4 under the NPSFM 2020 for suspended fine sediment. The national bottom line standard for suspended fine sediment is 0.98 m and therefore a turbidity of 5.5 NTU would apply when using the equation of Franklin et al. (2020) to convert visual clarity to turbidity.

The Motueka River at State Highway 60 monitoring site is located at the moment of the catchment and is the nearest downstream site to the Shaggery Creek confluence. The Motueka River has a New Zealand REC of CW/H/SS and therefore is Class 1 under the NPSFM (2020).

LAWA reports 5-year median turbidity for the Motueka River at this site of 0.98 NTU and reports a 5-year median visual clarity of 4.2m. A median visual clarity of 4.2m meets the standard for Band A under the NPSFM (2020) and meets the standard for suspended fine sediment. The current A band status represents the minimal impact of suspended sediment on instream biota and ecological communities are like those observed in natural reference conditions). A reduction in visual clarity to anything less than 2.95m would start having low to moderate impacts.

Overall, the visual clarity of the river is very good over the 5-year median period. However, there are periods in the available data record (as reported on the LAWA website) where visual clarity decreases to less than the national bottom line of <1.34m for Class 1 rivers. This is likely in response to flood events, and likely represents the distinct pulses of suspended sediment coming from the wider catchment. The A band status represents the minimal impact of suspended sediment on instream biota and ecological communities are like those observed in natural reference conditions. However, distinct pulses of sediment that give rise to reductions in visual clarity likely have short-lived effects on instream biota; as reported by James & McCallum (2015) where sediment inputs have at times resulted in sediment contributions to the sub-catchments and/or the main river. It is not unlikely that this behaviour is not experienced in other sub-catchments with key forestry activities occurring, like the Shaggery Creek catchment.

3.1.6 Golden Bay – Ligar Bay

Overview

Ligar Bay lies on the outskirts of the Abel Tasman National Park, on the south-east coast of Golden Bay. The bay's main population base resides across Ligar Bay and Pohara, and there are many holiday homes with a mixture of ages. The population expands in the summer months to experience the warm beaches, recreational activities and amenity values of the Bay. Recreational activities such as the Great Walks in the Abel Tasman National Park and pristine beaches are the main drawcard for the location (TDC, 2013). Within Ligar Bay there is a port with a boat club and a mix of commercial and recreational users.

The character of Ligar Bay is that of a small beachside township. It is located on flat land and gently sloping fans that extend up to a mixture of plantation forests (~140 ha), reverting indigenous scrub and some pasture in the steep hill county behind Ligar Bay. Much of this steep land and forestry is on highly erodible Separation Point Granite geology.

Onetahua Marae is located in Pohara. Following the closure of the cement works in Golden Bay, the local school was closed down and converted into the community marae, where they offered advanced building, landscaping, hydroponics, tourism and Te Reo lessons (Radio New Zealand, 2017). The local iwi cherishes the cultural heritage precincts within Ligar Bay with several identified archaeological sites in coastal locations. The adjoining Wainui Inlet is where Abel Tasman in 1642 first anchored into Golden Bay. This was the first meeting between Ngati Tumatakokiri and people of another race and is marked by a monument above Ligar Bay.

Between the 13 and 15 December 2011 the Pohara-Ligar Bay area in Golden Bay was hit by an extreme rainstorm which caused severe flooding, land sliding, and unexpected debris flows and debris floods, which resulted in the declaration of a civil defence emergency. Houses were affected by sediment and debris deposition from debris floods and flows. Sediment transported by debris floods reached the estuary behind Tata Beach. Following the 2011 event, GNS provided a report to the Tasman District Council on how to avoid/mitigate impacts of debris flow within the Ligar Bay/Pohara Valley. Nyhane Drive located in the heart of Ligar Bay is located on an alluvial fan, and it was recommended that vulnerable homes on the lower fan could be relocated to the upper fan (elevated terrace) that contained larger section sizes and were less vulnerable to debris floods and flows. Some areas were recommended as 'no-build' zones to avoid future damage to housing. GNS in their report highlighted land-use management changes in the upper catchment as having limited effects on the frequency of debris flows but some potential influence on their severity. Other land management suggestions included, for example, exotic forest slash removal at harvesting to reduce the amount of woody material able to be incorporated into debris flows. For production forest harvest operation "staging" the harvesting could manage the window of increased vulnerability post-harvest that occurs until a vegetative cover has been re-established. This highlights the severity of potential effects identified by the TDC and the vulnerability of the natural and built environment to potential landslides from mature forests that need to be harvested over the next few years in Ligar Bay.

Marine Environment

Areas considered to be outstanding natural features include the Ligar Bay estuary and Tarakohe Cliffs. The Ligar Bay estuary is a tidal lagoon and supports low vegetation dominated by gorse, flax, mahoe, bracken and marsh ribbonwood. The Tarakohe Cliffs are an Outstanding Natural Feature and are ancient limestone cliffs where towering northern rata trees dominate.

The Tarakohe Port contains 61 berths (mix of both commercial and recreational) and the port is set to be upgraded with $28-$35 million worth of investment. This is to support the expected growth in the mussel/aquaculture industry. The proposal also is wanting to extend the waka ama ramp, while separating the commercial uses from the recreational area for the health and safety of food and people. The port was crucial in goods distribution during Cyclone Gita. The Cyclone caused extensive debris flow damage to the road network.

Waterways

Council provides wastewater and stormwater services to most residential properties within the Pohara/ Ligar Bay/Tata Beach settlement area, as well as a rural residential road network with limited footpath connections. Council does not provide a public water supply to the full area, instead only servicing part of Pohara. Pohara water supply is taken from a stream and treated. The water treatment plant struggles to treat the water adequately when the stream is dirty or in flood, reflecting the impacts from surrounding land uses contributing sediment. The only public formed road provides access to Ligar Bay, Tata, Wainui Bay and the Abel Tasman National Park to the east, and therefore this access point is crucial for access to the local area.

In Ligar Bay, the drainage network consists of short, low order catchments that drain the gullies behind the Bay and connect directly to the coastal environment. These short, low order catchments primarily have a REC classification of WW/L/Pl or CW/L/Pl. There is no LAWA data for waterways within the Ligar Bay catchment. The REC classification makes the drainage network of Ligar Bay Class 2 or Class 4 for suspended fine sediment, and therefore a national bottom line for suspended sediment concentration of visual clarity <0.61 or <0.44 respectively. At this visual ranges, there is a high impact of suspended sediment on instream biota and ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

Using the established turbidity-visual clarity rating for New Zealand rivers (see Franklin *et al.,* 2020), annual median turbidity of 10.67 to 16.79 NTU would need to be maintained to remain in-line with suspended fine sediment limits. These two classes under the NPSFM (2020) have the lowest visual clarity standards for suspended fine sediment, in that there is some level of expectation that baseline (natural) sediment concentrations in these types of rivers are higher based on catchment characteristics. Despite this, forestry activities still likely play a role in elevated suspended sediment concentrations in the small, short order catchment of Ligar Bay that may reduce visual clarity further.

3.1.7 Summary

The main concerns with forest harvesting in the Tasman and Marlborough Districts have been the adverse effects of increased sediment yields and the deposition of fine suspended sediment in highly valued marine and freshwater environments, and debris flows carrying large volumes of forestry debris and woody organic material with potential to cause severe damage to property and assets.

The landscape and environmental factors that control the release of sediment and the frequency and occurrence of landslips and debris flows are heightened across Tasman and Marlborough due to steep topography and geology, and where this intersects land use activities with land disturbance activities, the risk of sediment and debris flows increases.

Hillslope connection and location of forestry activities appear to be important when reviewing historic events. However, even if landslips and debris flows do not directly enter the main stem of large waterways, debris flows and landslips can discharge large amounts of sediment and organic debris with these entering the main river from tributaries and the wider catchment area. This increases the scope for source determination of where mitigations across these landscapes are most important.

Sedimentation in the marine environment and effects on flora and fauna that result from sedimentation and landslide debris contravene several policies in the NZCPS. Therefore, where these impacts are observed, obligations under the NZCPS are not necessarily being meet, highlighting the need for effective regulatory tools.

Additionally, a halt on further degradation, i.e., further sedimentation in freshwater environments, is now mandated in the NPSFW by including suspended fine sediment and deposited sediment attributes in the NPSFM NOF with national bottom lines.

To meet the national bottom lines related to sediment in freshwater, every regional council must include rules in its regional plan that set environmental limits for Freshwater Management Units. Although the sediment attributes account for natural variation between different river types through a classification system, it will be difficult for foresters to meet these limits given the environmental characteristics of the streams and rivers where plantation forestry in Tasman and Marlborough is located.

There are significant pressures on foresters across Marlborough and Tasman to follow best practice management to ensure that forest activities are carried out in a way that minimises the risk of sedimentation, landslides and debris flows occurring. However, as highlighted by the Marlborough and Tasman case studies, the environments where plantation forestry are located are predisposed to slope failures that are compounded by the volume of debris in forests that exacerbate the potential effect and harm caused by land disturbance activities. Over time, sedimentation in these case study areas has occurred due to forestry activities.

In Tasman and Nelson, the TDC and Nelson City Council (NCC) require that all land disturbance activities (resource consents) have to prepare an erosion and sediment and control plan. Land use disturbances that are permitted activities also are required to have one of these plans—if not, then a resource consent is required. In Marlborough, the MDC has developed Environmental Guidelines for Forestry Harvesting.

The number of debris flow events that have occurred has highlighted a hazard that until recently was either not recognised or regarded as occurring very rarely in the Tasman and Marlborough Districts, and recent examples have shown the potential risks of harvesting forestry stands that were planting some 25-35 years ago. Regulation and best practice evolve through the forestry cycle and the highly desirable areas for plantation forestry 30 years ago, are potentially no longer as desirable, given subsequent experience. For example, for plantation forests planted on highly erodible Separation Point Granite, foresters and regulators are now faced with managing commercial gains with environmental impacts.

The Tasman and Marlborough districts have some of the clearest river water in New Zealand. With clear water it takes far less sediment to cause an effect on amenity values that is "conspicuous", and therefore it is highly likely that in these environments, sediment attributes in relation to the NPSFM NOF would not be met with the kinds of sediment discharges that typically occur from forestry activities.

There is still uncertainty on the effectiveness of the NES and the extent to which the NOF attributes are being achieved in relation to forestry activities. This is because the NESPF (2018) and NPSFM (2020) sediment attributes are still too recent to allow conclusions on how effective the relevant NESPF sediment regulations and NPSFM NOF have been. Assessment of the effectiveness of the NESPF sediment regulations and NPSFM NOF will be important to the development of a tool to support decision-makers and the forestry sector assess compliance with permitted standards and consent requirements.

4. A PROPOSED RISK ASSESSMENT TOOL

The NESPF consent and compliance guide directs councils to "develop systems and processes to effectively respond to the requirements in the NESPF". This means that there is opportunity for a tool to support this step in the effectiveness of the NESPF, as many activities that remain permitted activities through the use of Good Management Practices (GMPs) in low-risk environments will need a tool for assessing whether the right GMPs are in place based on the environment to remain compliant with standards.

The NES-PF permitted activity conditions require foresters to give councils notice of afforestation, earthworks, river crossings, forestry quarrying and harvesting prior to the activity commencing. Notice of these activities must be provided in writing to the relevant regional council within the specific timeframe. The NESPF permits plantation forestry activities where the risks are lower and permitted activity conditions can adequately manage actual and potential adverse environmental effects. While there is no specific obligation in the RMA to monitor permitted activities, undertaking this function in some way is recognised as good practice both for activities permitted under regional and district plans, and activities permitted under NES. The requirement to notify council of one of these activities means a suitably designed tool at this stage could be highly effective and support foresters and councils understand if an activity is going to need consent. This is particularly relevant where there is ambiguity surrounding the permitted standard for sediment discharges under the NESPF. This is particularly important for the plantation forestry activities that rely on permitted activity rules, and non-compliance may result in adverse environmental effects.

As part of the Envirolink project that this report contributes to, a method has been explored as an option for assessing whether the characterised impacts (consequences) will meet standards and whether the impacts can be practicably mitigated for freshwater and marine environments. For example, under the RMA framework, the challenge is to see if freshwater quality attributes would be achieved with a specific regulatory regime and/or specific mitigation measures. The method is a risk-based planning approach, and the intent is that this tool could support both the forestry sector and the agencies responsible for developing and implementing the planning/regulatory framework.

The issue of managing the impacts of harvest residues including sediment moving off-site is complex, as the large events that have the greatest potential for environmental impacts occur infrequently and are due to a combination of steeper slopes, weaker or more erodible soils, and larger rainfall events, or smaller rainfall events but with antecedent saturated soils. This makes defining a level of risk with the likely environmental consequences challenging.

For areas with potential risk of erosion, landslides and/or debris flows, advisors and decision-makers need to ensure that criteria set out in the plan and/or NESPF are considered. For example, the restricted discretionary activity matters for a resource consent application for forestry harvesting (NESPF Regulation 71) identify that "measures to minimise soil erosion during and after harvesting" be considered. This assumes that resource consent has been sought, which is not necessarily always the case with the reliance on permitted conditions. Therefore, any tool developed should consider both what is applicable when council is notified of a forestry activity, or a consent application has been made to the council.

Risk-based approaches are suitable where areas are already developed and specific activities are occurring that have some level of existing use rights (Saunders *et al.,* 2013). Risk-based assessment methods are developed via a series of key steps; the first is know your hazards, identify the consequences, establish the likelihood, take a risk-based approach, and lastly monitor and evaluate (Saunders *et al.,* 2013). The most challenging component of this concept is identifying consequences arising from the known hazard. In risk-based planning approaches, consequences can be intangibles such as community well-being, as well as more tangible impacts on the built environment or assets (Saunders *et al.,* 2013). Consequences can occur at multiple scales, including the built scale that includes social/cultural elements, and assets and infrastructure (Saunders *et al.,* 2013), and can be insignificant in nature or range up to catastrophic. A landslide risk matrix is a common way to assess the relationship between susceptibility to a landslide, the probability it will occur, and the magnitude of its impact in physical, social, cultural, and economic terms. The consequences will depend on the vulnerability and value of what is impacted, however what Saunders *et al.* (2013) do not detail is how to make this assessment for environmental consequences.

Many risk-based planning approaches exist, but few are specifically applied to environmental effects. It is often difficult to identify consequences for the natural environment using a risk-based assessment approach (Saunders *et al.,* 2013) because it is difficult to plan for the interaction between natural processes and activities that can create natural hazards. This is because the natural hazards that a risk-based planning approach is typically used for typically occur at unpredictable frequencies, for example, earthquakes or landslides that occur without anthropogenic influence. Furthermore, natural systems are complex and highly variable. A lack of data or understanding and the long-timescales for some environmental impacts can create uncertainty in risk-based planning approaches (EPA, 2007). However, uncertainty is not specific to risk analysis and is common to all methods of environmental analysis. Risk analysis provides a structured and systematic process that makes the best use of available information for making decisions about environmental issues and should not be disregarded for assessing the scale of the effect on the natural environment.

With robust tools, relevant technical information, and assessment methods e.g., remote sensing and mapping, it is possible to estimate the likelihood of landslides and debris flows in plantation forests, and assign a potential consequence based on an understanding of the existing environment and natural values present. This is best done by people with the best knowledge of the environment in question.

Therefore, a methodical approach taken to risk-based planning for the built environment could be applied to developing a similar system for the natural environment and specific hazards such as debris flows in plantation forests. To do this requires a method to rank effects based on the levels of consequence, from insignificant to catastrophic.

A method to categorise the consequences to the natural environment is presented by the South Australian EPA in a guide for planning professionals on using risk-based approaches in regulation. This method is based on an environmental harm index (Figure 1) and can be used to assess the sensitivity to sedimentation or a debris flow of certain freshwater and marine environments. Following this method, the above table template for defining environmental consequences could be used where the levels of consequence range from insignificant to catastrophic and can be fitted into other risk-based planning approaches to adopt these more traditional risk-based approaches to the need to assess environmental effects.

This approach developed by the South Australian EPA uses a definition of environmental harm from the Environment Protection Authority Act, applied within the framework of the Australian Standard AS/NZS 4360:2004 Risk management.

CONSEQUENCE	Level 5 High-level serious environmental harm	A5	B5	C5	D5	E5	F5	G5
	Level 4 Serious environmental harm	A4	B4	C4	D4	E4	F4	G4
	Level 3 Material environmental harm	A3	B3	C3	D3	E3	F3	G3
	Level 2 Environmental nuisance and default non-compliance	A2	B2	C2	D2	E2	F2	G2
	Level 1 Minor consequence	A1	B1	C1	D1	E1	F1	G1
		Daily or more often	Once a week or more often	Once a month or more often	Once a year or more often	Once in ten years or more often	Once in 100 years or more often	Less often than once in 100 years
		LIKELIHOOD						

Figure 2: Risk-matrix for environmental consequences (Source: EPA,2007)

Hazards such as landslides and debris flows can cause environmental harm in many ways as described in Section 3 of this report and can occur at a range of temporal and spatial scales, and to a broad range of receptors. Therefore, a hazard—pathway—receptor model provides an excellent tool for understanding the likely consequences and effect of a hazard. This hazard—pathway—receptor model describes the environmental setting of the site, potential contaminant sources, pathways for contaminant migration, and environmental receptors i.e., the marine environment or freshwater that could be adversely affected, and that receptors associated value will determine the level of consequence. In the EPA risk matrix above (Figure 1), likelihood is expressed as the period an event is predicted to occur in, such as daily, once a month, or once a year. In a forestry scenario, this could be the likelihood based on the annual exceedance probability that a debris flow occurs.

Table 2 below presents an example of possible environmental consequences adapted from Saunders and Glassey (2013) based on the level of consequence being insignificant to catastrophic. The description of the environmental impact is subject to further iterations depending on the preferences and policy directions of regional plans, other examples (MfE, 2010) have used *limited impacts on minimal areas* for insignificant environmental consequences and ranges up to *long-term widespread impacts and slow recovery* for catastrophic environmental consequences. This approach is also summarised in Table 2 below.

Table 2: Comparison of adverse environmental effects based on consequence rating (Sources: noted in heading for each column of the Table).

Adapted by M Bloomberg from Saunders and Glassey (Guidelines for assessing planning policy and consent requirements for landslide prone land. Saunders & Glassey, 2007)	South Australian EPA in a guide for planning professionals on using risk-based approaches in regulation (EPA, 2007).	New Zealand Ministry for Environment (example, MfE, 2010)
5. Catastrophic Permanent, severe and extensive adverse effects. Effects cannot be avoided, partial remediation or mitigation possible with difficulty and expense. Of concern at community, regional, national and possibly international level.	**Level 5: High level serious environmental harm** A high level of serious environmental harm occurs if it involves actual or potential harm to the health or safety of human beings that is of a high impact AND a wide scale, or other actual or potential environmental harm (not being merely an environmental nuisance) that is of a high impact AND a wide scale it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding $500 000.	Long-term, widespread impacts; slow recovery.
4. Major A local or extensive effect, highly visible or of high severity Adverse effects potentially permanent, mitigation will be expensive or difficult. Of concern at community, regional or national level.	**Level 4: Serious environmental harm** Environmental harm must be treated as serious environmental harm if: (i) it involves actual or potential harm to the health or safety of human beings that is of a high impact or on a wide scale, or other actual or potential environmental harm (not being merely an environmental nuisance) that is of a high impact or on a wide scale; or (ii) it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding $50 000.	Medium- to long-term widespread impacts.
3. Medium (Moderate) Local adverse effects are quite noticeable or severe. Adverse effects potentially permanent but can be mitigated. Of concern at community or regional level.	**Level 3: Material environmental harm** Environmental harm must be treated as material environmental harm if: (i) it consists of an environmental nuisance of a high impact or on a wide scale; or (ii) it involves actual or potential harm to the health or safety of human beings that is not trivial, or other actual or potential environmental harm (not being merely an environmental nuisance) that is not trivial; or (iii) it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding $5 000	Reversible medium-term local impacts.
2. Minor Local adverse effects are discernible but moderate. Adverse effects temporary, can be mitigated. Of concern at individual, community level	**Level 2: Environmental nuisance and default level for non-compliance** Environmental nuisance is: (a) any adverse effect on an amenity value of an area that— (i) is caused by pollution; and (ii) unreasonably interferes with or is likely to interfere unreasonably with the enjoyment of the area by persons occupying a place within, or lawfully resorting to, the area; or (b) any unsightly or offensive condition caused by pollution.	Reversible short-term impacts on local area.
1. Insignificant Adverse effects absent to minor, temporary, may not be discernible	**Level 1: Minor consequence** Harm that is below the threshold of environmental nuisance and does not breach the EP Act is categorised as minor.	Limited impacts on minimal area.

The above (Table 2) highlights that is not impossible to assign adverse effects to a 1-5 scale, but the definitions of the environmental effect are variable at the various consequence levels. This highlights the complexities of using a risk-based approach to anticipate environmental consequences and more specifically defining the scale and type of sediment/debris effects on waterways that would be insignificant to catastrophic, as there are multiple options for defining the environment effect that occurs on this 1-5 scale.

New Zealand has several documents that support best harvesting practices, but few collate, detail, or set standards for minimising debris flow risk (Visser, 2018). Visser (2018) addresses this somewhat by highlighting the common BMPs that are available to help maintain overall site stability, especially those related to infrastructure design and maintenance. Practices that minimise the risk of debris flow occurrence or the severity of the effect could be limiting the scale of clearcutting, use of streamside management zones, and avoiding the accumulation of harvesting residue (Visser, 2018). Where these fit within a risk-matrix as possible mitigations it is expected that these options represent a different level of risk management based on the likelihood of events occurring and the level of potential environmental impact.

The above method would require substantial investigation by scientists, resource management practitioners, stakeholders, and foresters to ensure the appropriate and best management practice measures are allocated to the appropriate consequence and likelihood of occurrence.

Based on an approach like the above, regulators and decision-makers could use existing or develop new geospatial tools to determine the risk of a landslide or debris flow from occurring. This approach assesses the level of harm from landslides, to support decisions on consent conditions and/or proposed mitigations and how restrictive these should be.

From the case study areas described in Section 3.1, it is clear based on the values present in the Marlborough and Tasman regions, in particular the marine and freshwater values of the natural environment, that the historic landslide events would be classified as more than minor.

The events reviewed in Section 3.1 each had different impacts based on the location and nature of the hazard that resulted from forestry activities. Interestingly, across the case studies are examples of forestry impacts that occur over long-time intervals, for example, the sedimentation on estuarine environments, and also much more rapid impact such as landslides and debris flows that cause significant damage to marine and freshwater environments. Estuarine and coastal sedimentation may be considered minor to medium in terms of scale of consequences but occur daily during the active period of forestry activity, for example the harvesting phase, and therefore be classified as A2 and A3 (in Table 1), and minor under the descriptions in Table 2. Here, it is easier to find consensus on what the environmental harm might be, and consent requirements/conditions could be employed. The determination of minor or medium may be the result of an assessment of the values of the environment, whether there is a nationally significant estuary at the bottom of the catchment or a highly productive marine farm. For larger, infrequent landslide or debris flows events, this typically occurs once in ten years to once in 100 years depending on the relevant annual exceedance probability for a location, and as evidenced in the case studies have moderate to catastrophic consequences. Therefore, these fall into D to G classes in Table 1 and are likely moderate to catastrophic depending on the description of the environmental harm applicable and the approach used, and maybe harder to define under a risk-based approach based on the timescale that these environmental consequences can occur (Table 2). Mitigations, consent requirements/conditions or even prohibited activity status would be relevant. The use of a risk-based approach like described here would support practitioners and foresters determine whether there is nil, less than minor, minor, more than minor, significant, or unacceptable effects when applying the NESPF under regulatory frameworks and determining the appropriateness of an activity under sections 104, 105 of the New Zealand Resource Management Act (1991).

5. CONCLUSION

Mass movement events and fine sediment production are caused by several interacting factors, many of which are related to the characteristics of the landscape and are exacerbated by heavy rainfall, which is particularly relevant across Marlborough and Tasman. This report has summarised these types of events and provided an overview of the environmental impacts. Previous events across Marlborough and Tasman have highlighted that hillslope connection, geology and topography, including the location of forestry activities as important drivers of landslides, debris flows and sediment loss.

This report has summarised the existing planning and regulatory framework that relates to forestry, and specifically considered the Marlborough and Tasman planning frameworks. The relevant plans have rules related to the discharge of sediment and/or organic debris with numerical permitted activity standards that apply to forestry activities. The pMEP and TRMP permitted activity rule wording provides additional clarity and direction compared to the permitted activity rules in the NESPF. However, the reliance of the NESPF on permitted activity rules means that there is a significant level of reliance on industry to ensure compliance. In addition, the reliance on narrative standards means that there is scope for uncertainty about defining "reasonable mixing" and "conspicuous change" in complex small river systems where many discharges may effectively be diffuse.

Effects of forestry on marine and freshwater environments is well documented and is receiving more attention as forests planted some time ago under different regulatory frameworks are now systematically being harvested and replanted as second or even third rotation crops. Of the effects well documented, the greatest potential for environmental impacts is from the larger more infrequent events such as landslides and debris flows that transport large amounts of sediment and woody debris quickly to freshwater and marine environments. There have been many well-documented occurrences of woody debris originating from commercial forestry catchments across Tasman and Marlborough and accelerated sedimentation at the coasts and in estuarine areas. These processes have undoubtedly had adverse effects on the flora and fauna of freshwater and marine environments.

Accelerated sedimentation in the marine environment caused by human activities and woody debris deposited at the coast is inconsistent with several policies in the NZCPS. Similarly accelerated sedimentation in freshwater environments is inconsistent with several NPSFM policies and with meeting relevant freshwater national bottom lines. Therefore, where these impacts are observed, obligations under the NZCPS and NPSFM are not necessarily being meet, highlighting the need for more effective regulatory tools. The length of time that the NESPF has been operating means that it has not been possible to specifically assess the effectiveness of the NESPF provisions.

This report has presented a possible risk assessment tool to support decision-makers that could be fine-tuned to environmental consequences. The approach is traditionally applied to the human (social, economic) and built (assets, infrastructure) environments as the outcomes are more predictable. To overcome this and apply a risk-based approach to environmental consequences, an additional step in the risk-matrix development process using a hazard—pathway—receptor model to rank the effects of events of different consequences (i.e., insignificant to catastrophic impacts) could be used.

It is recommended that MDC and TDC review opportunities like that explored in this report to support decision-makers. We think an approach like presented in this report, developed in collaboration with scientists, resource management practitioners, stakeholders, and foresters, can give decision-makers and foresters more certainty that effects from forestry are appropriately mitigated in highly valued environments.

6. REFERENCES

Abbott, S.K. (2006). *Cross-Scale Interactions Between Land Cover/Land Use, Climate, and River Water Quality: A Case Study of The Manawatu River Catchment, New Zealand.* Thesis submitted to the Graduate Council of Texas State.

Adams, K.N. & Fowler, A.M. (2006). Improving empirical relationships for predicting the effect of vegetation change on annual water yield. *Journal of Hydrology*, 321: 90-115.

Amishev, D., Basher, L., Phillips, C., Hill, S., Marden, M., Bloomberg, M. & Moore, J. (2014). *New Forest Management Approaches to Steep Hills.* Ministry for Primary Industries Technical Paper No: 2014/39.

ANZECC. (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 1. Canberra, Australia: Australian and New Zealand Environment and Conservation Council.

Baillie, B.R. & Rolando, C.A. (2015). Long-Term Management of Streams in Planted Forest Steeplands. *NZ Journal of Forestry,* 60(2): 21–24.

Basher, L.R., & Hicks, M. (2002). Sediment yield response to large storm events and forest harvesting, Motueka River, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* 45(3): 333-356.

Basher, L.R. (2013). Erosion processes and their control in New Zealand. In Dymond J.R. (eds). *Ecosystem services in New Zealand – conditions and trends.* Lincoln, New Zealand: Manaki Whenua Press.

Basher, L.R., Lynn, I.H. & Page, M. (2015). *Update of the Erosion Susceptibility Classification (ESC) for the proposed National Environmental Standard for Plantation Forestry – revision of the ESC*. Lincoln, New Zealand. Landcare Research.

Basher, L.R. & Hicks, M. (2003). *Review of existing data on erosion rates and sediment yield for the Motueka catchment: Progress Report.* Landcare ICM Report No. 2002-03/02. Christchurch, NZ: Landcare Research.

Basher, L.R., Hicks, D.M., Clapp, B. & Hewitt, T. (2011). Sediment yield response to large storm events and forest harvesting, Motueka River, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* 45(3): 333-356.

Bayne, K., Edwards, P. & Payn, T. (2019). Media coverage of recent New Zealand storm events. *New Zealand Journal of Forestry Science,* 64(1): 17-25.

Bilotta, G.S., & Brazier, R.E. (2008). Understanding the influence of suspended solids on water quality and biota. *Water Research,* 42: 2849–2861.

Bloomberg, M. (2011). Erosion susceptibility classification and analysis of erosion risks for plantation forestry – response to Marden et al. *NZ Journal of Forestry,* 60(2): 25-28.

Boam, E. (2018). *Whataroa Peninsula Forestry Block Slope Failures.* Wellington: WSP & OPUS

Buttle, J.M. (2011). The Effects of Forest Harvesting on Forest Hydrology and Biogeochemistry. In D.F. Levia, D. Carlyle-Moses, and T. Tanaka (eds). *Forest Hydrology and Biogeochemistry,* Springer, pp. 659.

Cabinet Paper. (2020). Action for Healthy Waterways – Decisions on National Direction and Regulations for Freshwater Management. Wellington, NZ: New Zealand Government.

Chang, M. (2006). Forest Hydrology, an Introduction to Water and Forests, Boca Raton Florida: CRC Press.

Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M. & Death, R.G. (2011). *Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values.* Nelson New Zealand: Cawthron Institute.

Clapp, B. (2009). *Motueka Forest sediment study: data report July 2006-June 2008 and analysis of sediment yield.* Reported prepared for Landcare Research Ltd and Tasman District Council. Sourced from online: https://icm.landcareresearch.co.nz/knowledgebase/publications/ (accessed 25 February 2021).

Coutts, G.L. & Urlich, S.C. (2020). *A local oral history of environmental change in Pelorus / Te Hoiere, Marlborough.* LEAP Research Report No 47. Lincoln, NZ: Lincoln University.

Croke, J.C. & Hairsine, P.B. (2006). Sediment delivery in managed forests: a review. *Environmental Reviews,* 14: 59-87.

Davidson, R. J. (2018*). Qualitative description of estuarine impacts in relation to sedimentation at three estuaries along the Abel Tasman Coast.* Prepared by Davidson Environmental Ltd. for Sustainable Marahau Incorporated. Survey and monitoring report no. 882.

Davidson, R.J., Richards, L.A., Rayes, C. & Scott-Simmonds, T. (2020). *Significant marine site survey and monitoring programme (survey 6): Summary report 2019-2020.* Prepared by Davidson Environmental Limited for Marlborough District Council. Survey and monitoring report number 1023.

Davies Colley, R., Hicks, M. & Hughes, A. (2015). *Fine sediment effects on freshwaters, and the relationship of environmental state to sediment load.* NIWA Report HAM2015-104. Hamilton, NZ: NIWA.

Doole, M.A. (2020). *Analysis of the 2018/19 Compliance, Monitoring and Enforcement Metrics for the Regional Sector.* The Catalyst Group Report 2019/152. Palmerston North, NZ: The Catalyst Group.

Dymond, J.R., Ausseil, A.G., Shepherd, J.D., & Buettner, L. (2006). Validation of a region-wide model of landslide susceptibility in the Manawatu–Wanganui region of New Zealand. *Geomorphology,* 74: 70–79.

Ekanayake, J., Marden, M., Watson, A. & Rowan, D. (1997). Tree Roots and Slope Stability: A comparison between Pinus radiata and Kanuka. *New Zealand Journal of Forestry Science,* 27(2): 216–233.

Environmental Protection Authority. (2007). *Environmental regulation using a risk-based approach—a guideline for EPA staff.* Adelaide, Australia: Environmental Protection Authority.

EPA. (2007). *Environmental regulation using a risk-based approach—a guideline for EPA staff.* Adelaide, South Australia: Environmental Protection Authority.

Fahey, B. & Jackson, R. (1997). Hydrological impacts of converting native forests and grasslands to pine plantations, South Island, New Zealand. *Agriculture and Forest Meteorology,* 84: 69-82.

Fahey, B. (1994). The effect of plantation forestry on water yield in New Zealand. *New Zealand Journal of Forestry,* 39(3): 18-25.

Fowler, C. & Buddle, M. (2020). Major environmental law reform affecting the plantation forestry sector. *New Zealand Journal of Forestry,* 64(3): 3-9.

Franklin, P., Booker, D. & Stoffels, R. (2020). *Turbidity and visual clarity threshold conversion.* Contract 23184: Task 2. Hamilton, NZ: NIWA.

Fransen, P., McMahon, S., Gillepsie, P. & Asher, R. (1998). Effects of Logging on the Marine Environment at Onepua Bay, Marlborough Sounds. *New Zealand Journal of Marine and Freshwater Research,* 43(3): 13-18.

Geertsema, M., Highland, L., & Vaugeouis, L. (2009). *Environmental impact of landslides.* In Landslides–Disaster Risk Reduction (pp. 589-607). Springer, Berlin, Heidelberg.

Gillespie, P. (2007). Potential Effects of High Sediment Loads on the Marine Environment of the East Coast of the North Island, East Cape - Hawke Bay: A Review of Existing Information. Prepared for Gisborne District Council. Cawthron Report No. 1389. Nelson, NZ: Cawthron Institute.

Glade, T. (2003). Landslide occurrence as a response to land use change: a review of evidence from New Zealand. *Catena,* 51: 297-314.

Griffiths., J.W., Lukes, C.E., & May, R. (2020). Increased forest cover and limits on clear-felling could substantially reduce landslide occurrence in Tasman, New Zealand. *New Zealand Journal of Forestry Science,* 50(13): 1179-5395.

Handley, S. & Brown, S. (2012). *Feasibility of restoring Tasman Bay mussel beds.* NIWA Client Report No. NEL2012-013. Nelson, New Zealand: NIWA.

Handley, S., Gibbs, M., Swales, A., Olsen, G., Ovenden, R. & Bradley, A. (2017). *A 1,000 year history of seabed change in Pelorus Sound/Te Hoiere, Marlborough.* NIWA client report 2016119NE. Nelson, New Zealand: NIWA.

Henkel, S. (2019). *Water Quality in the Linkwater Area.* MDC Report No: 19-005. Blenheim, New Zealand: Marlborough District Council.

James, T. & McCallum, J. (2015). *State of the Environment Report: River Water Quality in Tasman District 2015*. Prepared for Tasman District Council.

Johnston A., Mace J., & Laffan M. (1981). The saw, the soil, and the Sounds. *Soil & Water*, Aug/Oct 1981: 4-8.

Laffan M.D., McQueen D.J., Churchman G.J. & Joe E.N. (1985). Soil resources of the Marlborough Sounds and implications for exotic production forestry. 2. Potential site disturbance and fine sediment production from various forest management practices. *NZ Journal of Forestry*, 30: 70-86.

Laffan, M.D., McQueen, D.J., Churchman, G.J., & Joe, E.E. (1981). The saw, the soil and the sounds. *Soil and Water,* 17(3/4): 4-8.

Marden, M. & Rowan, D. (2015). The effect of land use on slope failure and sediment generation in the Coromandel region of New Zealand following a major storm in 1995. *NZ Journal of Forestry Science,* 45(10). DOI 10.1186/s40490-015-0036-9.

Marden, M., Rowe, L., & Rowan, D. (2007). Slopewash erosion following plantation harvesting in pumice terrain and its contribution to stream sedimentation, Pokairoa catchment, North Island, New Zealand. *Journal of Hydrology (NZ),* 46(2): 73-90.

Marden, M., Phillips, C. & Rowan, D. (2002). *Soil loss, vegetation recovery, and sediment yield following plantation harvesting, Coromandel – interim results.* Lincoln, New Zealand: Landcare Research.

Marden, M., Lambie, S. & Phillips, C. (2018). Biomass and root attributes of eight of New Zealand's most common indigenous evergreen conifer and broadleaved forest species during the first 5 years of establishment. *New Zealand Journal of Forestry Science*, 48(9). DOI:10.1186/s40490-018-0113-y.

Ministry for the Environment. (2019). *New Zealand 's Environmental Reporting Series: Environment Aotearoa 2019.* Wellington, NZ: Ministry for the Environment.

Ministry for the Environment. (2010). *Preparing for future flooding: A guide for local government New Zealand.* Wellington, NZ: Ministry for the Environment.

Neal, C., Fisher, R., Smith, C.J., Hill, S., Neal, M., Conway, T., Ryland, G.P. & Jeffery, H.A. (1992) The effects of tree harvesting on stream-water quality at an acidic and acid-sensitive spruce forested area: Plynlimon, mid-Wales. *Journal of Hydrology,* 135: 205-319.

Neary, D.G., Pearce, A.J., O'Loughlin, C.L. & Rowe, L.K. (1978) Management impacts of nutrient fluxes in beech-podocarp-hardwood forests. *New Zealand Journal of Ecology,* 1: 19-26.

Newcombie, E. & Johnston, O. (2016). *Picton Bays Environmental Information and Health Assessment.* Cawthron Report 2805. Nelson, NZ: Cawthron.

O'Loughlin, C.L., Rowe, L.K. & Pearce, A.J. (1984). Hydrology of mid-altitude tussock grasslands, Upper Waipori Catchment, Otago: 1 – erosion, sediment yields and water quality. *Journal of Hydrology New Zealand,* 23(2): 45-59.

O'Loughlin, C. (2005). The protective role of trees in soil conservation. *NZ Journal of Forestry*, February 2005.

Page, M.J. (2013). *Landslides and debris flows caused by the 15-17 June 2013 rain storm in the Marahau-Motueka Area, and the fatal landslide at Otuwhero Inlet.* Report 2013/44. Wellington, NZ: GNS Science.

Phillips, C., Marden, M. & Basher, L. (2017). Geomorphology and forest management in New Zealand's erodible steeplands: An overview. *Geomorphology*, 307: 107-121. DOI: 10.1016/j.geomorph.2017.07.031.

Phillips, C., Marden, M. & Basher, L. (2012). Plantation Forest Harvesting and Landscape Response – What we know and what we need to know. *NZ Journal of Forestry,* 56(4): 4-12.

Quinn, J.M., Cooper, A.B., Davis-Colley, R.J., Rutherford, J.M. & Williamson, B. (1997). Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams*. Journal of Marine and Freshwater Research,* 31(5): 579-597.

Ranford, C. (2020). Work begins on multimillion-dollar project to restore water quality in Marlborough Sounds catchment. Source online: https://www.stuff.co.nz/national/politics/local-democracy-reporting/300057811/work-begins-on-multimilliondollar-project-to-restore-water-quality-in-marlborough-sounds-catchment (accessed 21 December 2020).

Radio New Zealand. (2017). Golden Bay's multicultural marae. Source online: https://www.rnz.co.nz/national/programmes/teahikaa/audio/201835296/golden-bay's-multicultural-marae (accessed 13 January 2021).

Ryan, A. (1991). Environmental effects of sediment on New Zealand streams: A review. *New Zealand Journal of Marine and Freshwater Research,* 25(2), 207-221.

Satchell, D. (2018). *Report: Trees for steep slopes.* Farm Forestry New Zealand, sourced online: https://www.nzffa.org.nz/farm-forestry-model/why-farm-forestry/trees-for-erosion-controlsoil-conservation/report-trees-for-steep-slopes/ (accessed 25 February 2021).

Saunder, W. & Glassey, P. (2007). Guidelines for assigning planning policy and consent requirements for landslide prone land. GNS Science Miscellaneous Series 7.

Saunders, W.S.A., Beban, J.G. & Kilvington, M. (2013). *Risk-based land use planning for natural hazard risk reduction.* GNS Science Miscellaneous Series 67.

Scion. (2017). *Debris Flows: New Zealand planted forests environmental facts.* Rotorua, New Zealand: Scion.

Simpson Grierson. (2010). *Case law on limits for freshwater quality and environmental flows.* Auckland, New Zealand: Simpson Grierson.

Sivignon, C. (2018). Onto the roof as Shaggery Creek, near Motueka, becomes a torrent. Source online: https://www.stuff.co.nz/nelson-mail/news/101642344/couple-clamber-on-roof-as-shaggery-creek-becomes-torrent (accessed 18 January 2021).

Snelder, T., Biggs, B. & Weatherhead, M. (2010). *New Zealand River Environment Classification User Guide.* Wellington, NZ: NIWA.

Tasman District Council. (2019). *Erosion and Sediment Control Guidelines.* Nelson, NZ: Tasman District Council.

TDC. (2013). Debris Flow Hazard in Pohara and Ligar Bay. Tasman District Council Full Council Agenda – 27 June 2013. Report No. RCN13-06-21.

Te Atiawa & MDC. (2018). Waitohi and Waikawa Streams Characterisation Study. Blenheim, New Zealand: Marlborough District Council.

Urlich, S.C. (2015). *Mitigating Fine Sediment from Forestry in Coastal Waters of the Marlborough Sounds.* MDC Technical Report No: 15-009. Marlborough, NZ: Marlborough District Council.

Urlich, S.C. (2020). Opportunities to manage sediment from forestry more effectively in the Marlborough Sounds and contributing catchments. *New Zealand Journal of Marine and Freshwater Research*, 65(2): 28-35.

Visser, R. (2018). *Best practices for reducing harvest residues and mitigating mobilisation of harvest residues in steepland plantation forests.* Enviro Link Contract 1879-GSD152. Christchurch, NZ: School of Forestry, University of Canterbury.

Visser, R. & Harvey, C. (2020). *Design of Debris Slash Traps: Considerations for NZ Plantation Forestry Operating.* Enviro Link Contract. Christchurch, NZ: School of Forestry, University of Canterbury.

Woodward, J. & Foster, I. (1997). Erosion and suspended sediment transfer in river catchments: environmental controls, processes and problems, *Geography,* 82(4): 353-376.