Boffa Miskell

TE HAKAPUPU | PLEASANT RIVER CATCHMENT FLOODING HAZARDS

FEASIBILITY STUDY OF NATURE-BASED SOLUTIONS

18 FEBRUARY 2025

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EXECUTIVE SUMMARY

The use of Nature-based Solutions (NbS) within Te Hakapupu/Pleasant River catchment (the catchment) present significant opportunities to manage flooding and associated hazards. However currently, in New Zealand, the understanding and use of NbS as a tool to manage flood hazards remains in its infancy. To help build a strong evidence-base to inform the future use of NbS for flood hazard management across Otago, Otago Regional Council (ORC) has commissioned a feasibility study of NbS to manage flood hazards in Te Hakapupu/Pleasant River catchment.

The study will look at how NbS could help lessen the long-term effects of flooding in Otago, as well as bring other benefits to the region. The project is one of 21 nationally to be fully funded by the Ministry for the Environment's (MfE) Essential Freshwater Fund. In addition, the work builds on and supports Toitū Te Hakapupu: The Pleasant River Catchment Restoration Project, a partnership between Otago Regional Council and Kāti Huirapa Rūnaka ki Puketeraki to restore and enhance the mauri and health of the river system.

BUILDING AN UNDERSTANDING OF NATURE-BASED SOLUTIONS

Te Hakapupu/Pleasant River catchment in East Otago currently faces challenges from flooding and associated hazards, including streambank erosion and sedimentation, that occur during an extreme rainfall event. These challenges are commonly experienced in catchments across the Otago Region and wider New Zealand. As the effects of climate change continue to grow, the frequency and intensity of extreme rainfall events in the Otago Region are projected to increase, placing additional pressures on local communities and natural environment values.

NbS have the potential to effectively manage flood hazards in the catchment and other similar catchments in the Otago region. Taking actions to protect, conserve, restore, and sustainably use natural ecosystems can increase resilience to the effects of flood hazards, while simultaneously providing a wide range of social, economic, environmental, and cultural benefits.

As part of the feasibility study, several NbS interventions were evaluated to establish their flood hazard management capabilities, their alignment with global standards for NbS best practice, and their relevance to the catchment and its characteristics. A Rapid Flood Hazard Model was also developed to assist with understanding how the proposed NbS could affect the existing flood events in the catchment.

Three NbS interventions were identified as being feasible within Te Hakapupu/Pleasant River catchment.

1. **Landcover management:** Restoring and expanding existing pockets of remnant indigenous forest, working towards the gradual transition of large areas of landcover to permanent indigenous forest in vulnerable upper sub-catchment locations
2. **River and stream naturalisation:** Restoration of riparian vegetation, re-meandering channels, and reconnecting isolated or drained off-stream wetland areas along the catchments modified and unvegetated waterways
3. **Wetland restoration and construction:** Restoring and constructing surface flow wetland natural features, such as deep sedimentation ponds and shallow water vegetated areas in flood prone catchment locations

The possible application of these interventions across a typical river catchment is illustrated in Figure 1.

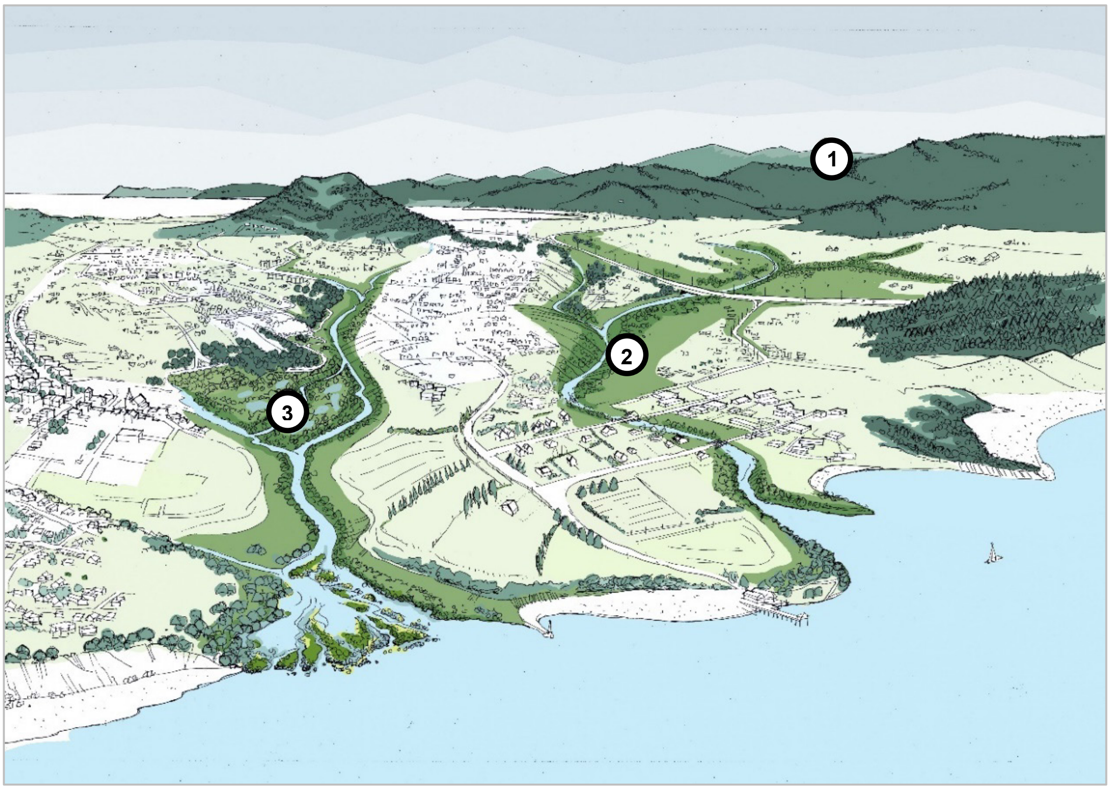


Figure 1: Possible application of the three nature-based solutions across an illustrative river catchment. 1: Landcover management; 2: River and stream naturalisation; and 3: Wetland restoration and construction. Source: Boffa Miskell Ltd.

The three NbS interventions were all assessed to provide significant benefits to flood hazard management within the catchment. They would also deliver a wide range of social, economic, environmental, and cultural benefits and support local catchment management goals currently being delivered by Toitū Te Hakapupu: The Pleasant River Catchment Restoration Project.

CHALLENGES FOR NATURE-BASED SOLUTIONS

While NbS interventions were evaluated to be technically feasible and beneficial for addressing flooding and associated hazards experienced within Te Hakapupu/Pleasant River catchment, at present, their practical application faces several barriers.

To sufficiently manage flood hazards in the catchment, NbS need to be considered at a catchment scale, across multiple land tenures. Specifically, in Te Hakapupu/Pleasant River catchment, it is recommended to progress landcover management in the upper catchment, before applying NbS in the lower catchment. This will safeguard against flood hazards currently experienced further downstream, during forestry harvest and replanting periods.

However, to do this, would require areas of land currently used for commercial forestry to be set aside for non-commercial native forest use.

Accordingly, in considering the large-scale land-use changes needed for NbS, the most significant challenges preventing their use would be the direct economic costs experienced by landowners from the loss of primary production lands (both forestry and agriculture).

To overcome these challenges and facilitate the wider use NbS in Te Hakapupu/Pleasant River catchment and other Otago catchments, it is recommended that a range of governance measures and economic incentives are in place that could encourage landowners to invest in NbS in the catchment.

FEASIBILITY STUDY KEY FINDINGS

Through the process of undertaking the feasibility study a number of key findings were established, that could guide the ongoing use of NbS as tools to manage flood hazards in Te Hakapupu/Pleasant River catchment and across the wider Otago region. It is recommended that these are tested further with ORC partners and stakeholders, including landowners, operators and investors, and the local community.

NbS are technically feasible

NbS are technically feasible as methods for the management of flooding and associated hazards in Te Hakapupu/Pleasant River catchment and across the wider Otago region. NbS will work to influence the natural processes across the catchment to effectively control and accommodate floodwater, and their use should be promoted as a method of flood mitigation.

Landcover management in upper catchment areas is the first step

Implementing land cover management NbS in the upper Te Hakapupu/Pleasant River catchment is critical to manage flooding and associated hazards, which are expected to increase in the lower catchment, during upper catchment forestry harvest periods.

NbS work most successfully when applied at scale

In a large catchment like Te Hakapupu/Pleasant River, to sufficiently manage flooding and associated hazards NbS should be applied at a suitably large scale[1]. NbS are most effective when implemented over larger areas or broader contexts, and while small-scale NbS projects can be useful, scaling them up maximises their ecological, economic, and social benefits.

Integrated NbS provide enhanced benefits

At scale, NbS need to work in an integrated manner to effectively manage flood hazards, working as a connected network and with surrounding land uses, across the catchment, from Ki Uta Ki Tai (mountains to the sea). When NbS are integrated across catchment areas their effectiveness and benefits are significantly enhanced.

Innovation is required to ensure NbS are economically viable

The current economic and funding framework presents one of the greatest challenges to NbS implementation, making them financially unviable for many landowners. To support large-scale adoption of NbS, especially across areas of productive forestry and farming land use like Te Hakapupu/Pleasant River catchment, innovative economic approaches are essential.

[1] E.g. The scale of a constructed wetland should be 1-5% of the contributing catchment area to effectively manage flooding and reduce contamination

RECOMMENDED ACTIONS TO SUPPORT THE USE OF NATURE-BASED SOLUTIONS

Successfully applying NbS will require strong governance and political backing, as well as economic support and financial assistance, for landowner, from both the private and public sectors. This could involve approaches like payments for environmental benefits, financial incentives for landowners, and cost sharing initiatives.

The following five actions are recommended to facilitate the practical implementation of NbS in Te Hakapupu/Pleasant River catchment and other similar catchments across the Otago region:

Action 1: Strengthen NbS governance and partnerships

Create innovative public and private partnerships, involving central and local governments, mana whenua, landowners, businesses, financial institutions, and community stakeholders to create a robust governance framework, that supports equitable application and funding of NbS for hazard management, and encourages time and financial investment by all parties.[2]

Action 2: Facilitate economic incentives for landowners

Develop and implement a model that provides economic incentives to landowners for transitioning existing land uses to NbS, (e.g. retiring productive farmland to become wetland). This could include mechanisms such as payments for ecosystem services, grants, tax incentives, and revenue from ecotourism.

Action 3: Promote Nature-based credit markets

Build greater understanding and application of the nature-based markets available for ecosystem services, and how they can be used to enable private investment in NbS as a tool to manage flood hazards (e.g. ability for private companies to finance NbS and associated carbon and biodiversity benefits to offset carbon emissions).

Action 4: Develop regional NbS policy, guidance, and standards

Develop NbS practice standards, guidance and supporting regional policies tailored for the Otago region to support landowners in adopting and implementing NbS on their properties. This includes ensuring consistency across the region by providing comprehensive guidance for NbS planning, addressing the required consenting pathways to streamline implementation

Action 5: Integrate NbS into catchment scale management and planning

Nature based solutions should be planned for and integrated within the Te Hakapupu Catchment Action Plan, and for other similar Otago region catchments through Integrated Catchment Management Planning (ICMP) processes to ensure they're used correctly and cohesively with catchment land uses and community values.

[2] Financial institutions include banks, insurance companies, and other investment companies. These institutions are important to facilitating investment via tools such as green bonds and sustainability-linked loans

1. INTRODUCTION

1.1. PURPOSE OF THE NATURE-BASED SOLUTIONS FEASIBILITY STUDY

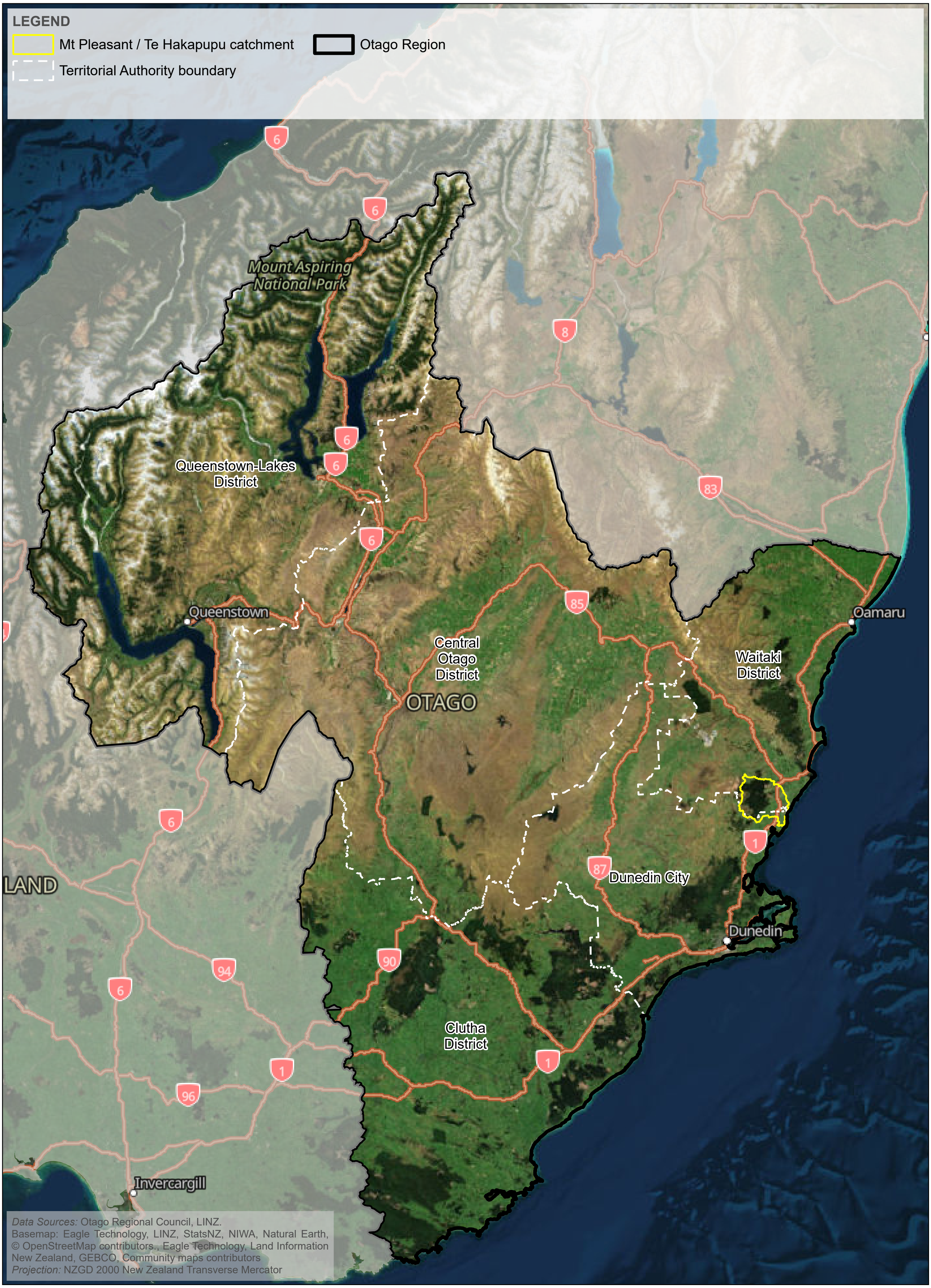
Boffa Miskell has been commissioned by Otago Regional Council (ORC) to undertake a feasibility study to investigate the use of nature-based solutions (NbS) in managing flooding and associated hazards in Te Hakapupu/Pleasant River catchment (the catchment).

The catchment is in Eastern coastal Otago (see Map 1) and covers about 12,800 hectares of rural land. It sits within the regional jurisdiction of ORC and spans the local authority boundaries of Dunedin City Council (DCC) and Waitaki District Council (WDC). The catchment includes Te Hakapupu / Pleasant River, Owhakaoho/Trotters Creek, Watkin Creek, and the Te Hakapupu / Pleasant River estuary wetland complex (see Map 2). The catchment is within the takiwā (territory) of Kāti Huirapa ki Puketeraki, who hold mana whenua status over East Otago and kaitiakitaka (guardianship) of the land.

The NbS feasibility study will inform ORC and its partners collective understanding of NbS and their benefits. It tests the viability of three NbS in managing flooding and associated hazards in the catchment and sets out several recommendations to take forward in the future. In addition, a key objective was to enable the transfer of the learnings from the study to other river catchments in the Otago region.

The NbS feasibility study will help ORC and its partners to:

- Establish an understanding of NbS based on global and national best practice, their benefits, and obstacles and barriers to implementation
- Understand how Te Hakapupu/Pleasant River catchment behaves in different extreme rainfall events, including during predicted peak flood periods
- Test how NbS best practice could contribute to flood hazard management in Te Hakapupu/Pleasant River catchment
- Provide recommendations for how ORC and relevant parties could work together to use NbS as a flood management tool in Te Hakapupu/Pleasant River catchment.
- Build upon the efforts and progress of the Toitū Te Hakapupu: Pleasant River restoration project, as a foundation to introduce and expand NbS within the catchment area.
- Establish regional NbS guidance, standards, and policy to enable the learnings from this study to be transferred to any catchment on Otago.



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TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

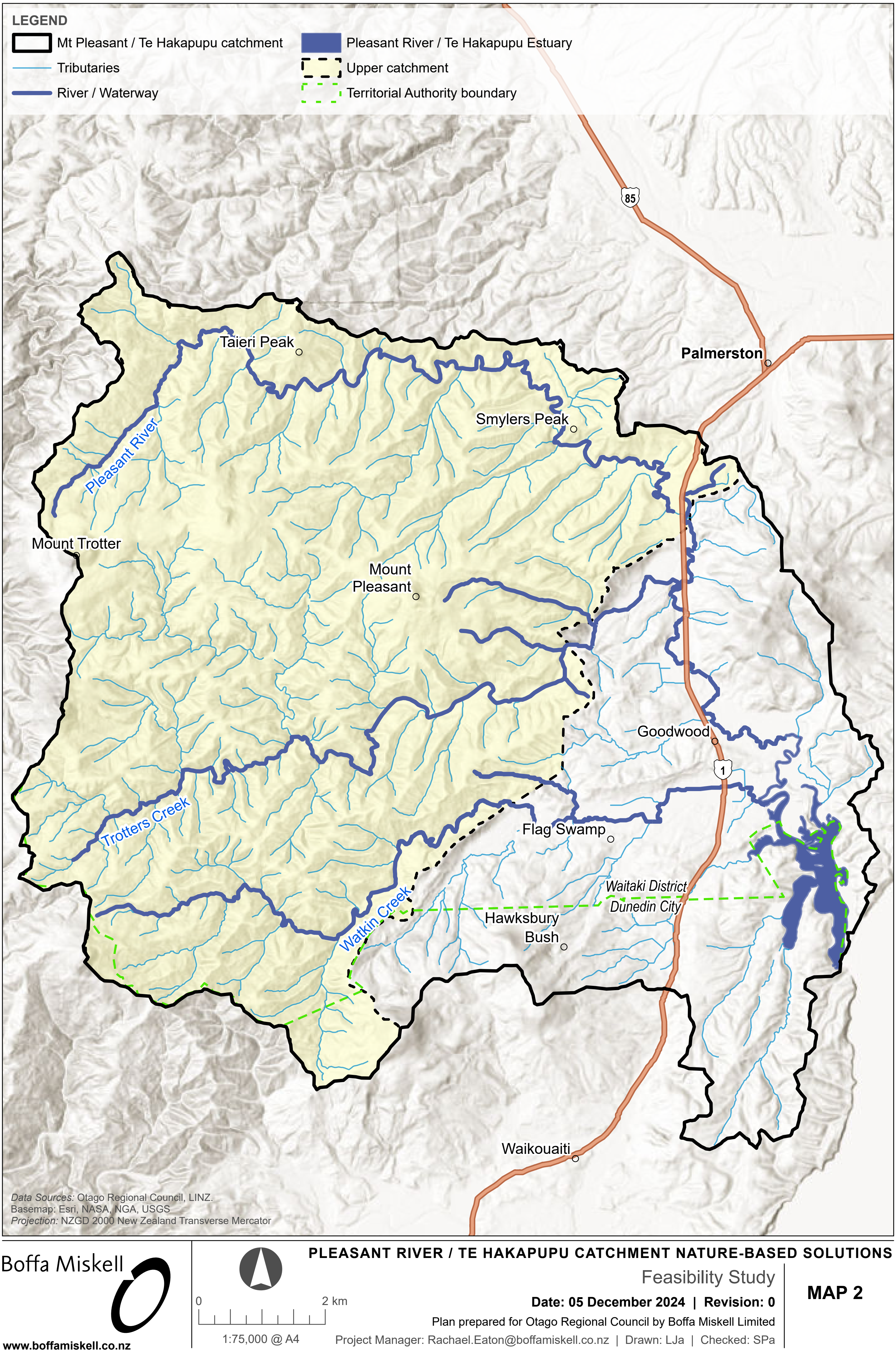
Catchment Location

Date: 04 December 2024 | Revision: 0

Plan prepared for Otago Regional Council by Boffa Miskell Limited

Project Manager: Rachael.Eaton@boffamiskell.co.nz | Drawn: LJa | Checked: SPa

MAP 1



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Feasibility Study

Date: 05 December 2024 | Revision: 0

Plan prepared for Otago Regional Council by Boffa Miskell Limited

Project Manager: Rachael.Eaton@boffamiskell.co.nz | Drawn: LJa | Checked: SPa

MAP 2

1.1.1 Toitū Te Hakapupu: The Pleasant River Catchment Restoration Project

In 2021, the catchment received funding from the Ministry for the Environment 'Essential Freshwater Fund' to support the Toitū Te Hakapupu – Pleasant River Catchment Restoration Project.[3] The project is a four-year partnership between the Otago Regional Council (ORC) and Kāti Huirapa Rūnaka ki Puketeraki.

The $5.2 million project is focused on improving the health of the water in the catchment which includes Owhakaoho/Trotters Creek, Watkin Creek, and the estuary. It aims to restore and enhance the mauri and health of this important river system.

Since its establishment, the project has conducted environmental monitoring to understand the current pressures on the catchment and supported landowners to plant approximately 68,000 plants and erect 27 km of fencing for freshwater enhancement.

See Appendix 4 for Toitū Te Hakapupu – Pleasant River Catchment Restoration Project native planting and fencing statistics (as of December 2024).

[3] Toitū Te Hakapupu: The Pleasant River Catchment Restoration Project | Otago Regional Council

1.2 FEASIBILITY STUDY METHODOLOGY

The methodology for evaluating the feasibility of NbS in Te Hakapupu/Pleasant River Catchment has been grounded on international NbS best practice, supported by collaboration with ORC, mana whenua, and community stakeholders.

Building upon an established understanding of NbS global and national best practice, a strong understanding of the catchment was developed through hydrology modelling, geospatial analysis, and catchment specific literature review. At key stages throughout the delivery of the feasibility study, engagement with the Toitū Te Hakapupu Partnership Group and other community stakeholders was conducted to gather additional insights and test findings.

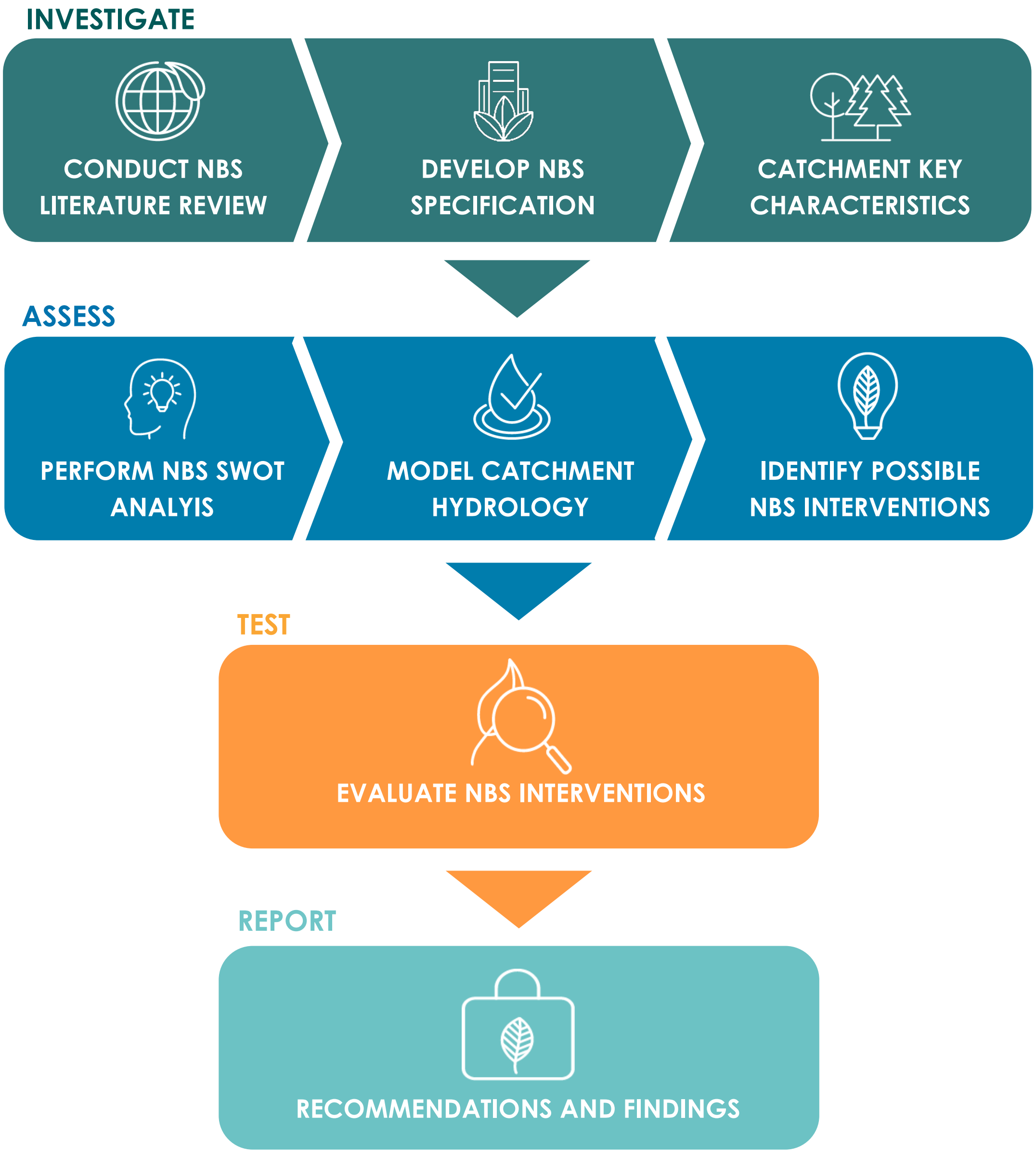


Figure 2: Overview of the Feasibility Study methodology

Investigation

To establish an understanding of NbS for flood management that could be applied in Te Hakapupu/Pleasant River catchment, a literature review was conducted. Based on leading international NbS literature sources, including the International Union for the Conservation of Nature (IUCN), the Nature-based Solutions Initiative, and the US Army Corps of Engineers, a variety of NbS approaches for flood hazard mitigation were identified for further investigation. Additionally, the literature review sought to uncover emerging NbS best practice standards and evaluation practices that should be considered throughout this feasibility study.

Applying the *IUCN 'Global Standard for Nature-based Solutions' (2020)* identified during the literature review, a 'Nature-based Solutions Technical Specification' was developed. This set the technical framework for the project, confirming the definition, functional criteria, and performance indicators to be used to design and evaluate NbS in the Otago region. The specification was developed to ensure NbS interventions proposed within Te Hakapupu/Pleasant River catchment reflect best practice guidelines and align with global NbS standards and agreements. See Appendix 1 for more information on the Technical Specification.

A spatial analysis was conducted for the catchment area to identify district plan landscape features and constraints, natural hazard zones, land uses, and remnant indigenous ecosystem coverage. Building upon this spatial information, a catchment specific literature review provided a strong understanding of the key catchment characteristics, environmental pressures, and values. This included gathering information concerning the water quality challenges in the catchment, mana whenua and community objectives for the catchment, and how the catchment would be affected by the projected impacts of climate change in the Otago region.

Assessment

Based on the various NbS approaches identified during the literature review, a SWOT (strengths, weaknesses, opportunities, and threats) analysis process was then conducted to assess and refine the use of NbS for flood hazard management in the catchment. This process sought to identify the key NbS that were deemed to most compatible within the environmental, social, and economic content of the Te Hakapupu/Pleasant River catchment. The SWOT analysis was conducted with input from technical experts, ORC project team members, Kati Huirapa Rūnaka ki Puketeraki, forestry operators, and the East Otago Catchment Group.

From the SWOT analysis, three NbS interventions were identified. These NbS were landcover management, river and stream naturalisation, and wetland restoration and construction.

Testing and evaluation

The three NbS interventions were tested in the catchment to understand their feasibility for flood hazard management. Using the functional criteria and relevant performance indicators from the NbS Technical Specification, and the Rapid Flood Hazard Modelling (RFHM) detailed below, an evaluation criterion was applied to each NbS intervention to test the opportunities, challenges, and possible benefits of NbS.

The evaluation of NbS interventions was conducted by technical planning, ecology, hydrologists, and landscape experts. To ensure interventions fit practically within existing landscape constraints and contribute to flood management, evaluations were further informed by the RFHM data and catchment geospatial information (GIS).

Evaluation considerations included the flood hazard management capability of NbS interventions, alongside the other possible benefits of NbS such as biodiversity, landscape character, economic value, and social benefits.

Findings and next steps

Outcomes of the evaluation processes and RFHM analysis have been collated in this feasibility study, with accompanying technical appendices and GIS resources provided. The conclusion of this feasibility study outlines the key findings and recommended actions needed for the successful implementation of NbS for flood management in Te Hakapupu/Pleasant River Catchment and other Otago catchments. These insights provide a foundation for informed decision-making and practical action across the region.

1.2.2 Rapid Flood Hazard Modelling

To inform the Te Hakapupu/Pleasant River catchment NbS feasibility study, Boffa Miskell commissioned hydrology modellers and technical experts to produce and analyse a Rapid Flood Hazard Model (RFHM) of the catchment.

This modelling characterises how the current catchment will likely respond during an extreme rainfall event, in this case a one-in-100-year rainfall event (100-year annual return interval) with the added effect of climate change. The model simulates how rain, captured in the steeper inland areas of the upper catchment, flows through the main channels of Te Hakapupu / Pleasant River, Owhakaoho / Trotters Creek, and Watkin Creek into the flatter areas of the lower catchment.

The RFHM process aimed to establish and understand the expected characteristics of flood risks in the catchment during a one-in-10-year and one-in-100-year, 24-hour extreme rainfall event under future climate change scenario. RFHM outputs included predicted peak flood flow level, peak flood depth, and peak flood flow speed.

The RFHM helped to establish how the use of NbS would affect the predicted peak flood in the catchment, and their potential use in reducing flood magnitude and mitigating flood risks.

These findings, combined with coastal inundation modelling and the qualitative findings of this feasibility report, provides a suite of tools to evaluate how NbS and other flood management interventions may impact flood characteristics in the catchment. These tools will support the evolving understanding and application of NbS in the area and across the Otago region.

See Appendix 2 for more information about the RFHM process and outputs.

WHAT ARE NATURE-BASED SOLUTIONS?

Credit: Boffa Miskell Ltd

2. WHAT ARE NATURE-BASED SOLUTIONS?

2.1 DEFINING NATURE-BASED SOLUTIONS

Nature-based solutions seek to use natural processes to address environmental challenges, like flood hazards and risks, while providing biodiversity, human wellbeing, and community benefits

This NbS feasibility study uses the definition of NbS, formerly adopted by the United Nations Environment Assembly 2022 (UNEA). This definition builds upon the International Union for Conservation of Nature (IUCN) definition of NbS and other relevant NbS definitions formerly use to provide an internationally agreed approach for NbS.

'Nature-based solutions are actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic, and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience, and biodiversity benefits' – (UNEA/EA.5/Res.5)

At present in New Zealand, a number of different definitions for NbS exist within various strategic planning frameworks, including council climate change and biodiversity strategies, the National Adaptation Plan, and Te Mana o te Taiao - Aotearoa New Zealand Biodiversity Strategy.[4] However, following the formal adoption on the UNEA NbS definition, work is currently underway by the Ministry for the Environment to communicate this collective definition across New Zealand NbS users.

To support the assessment of the feasibility of NbS for flood mitigation, currently being conducted by ORC and other regional or unitary councils, the Ministry of Business, Innovation, and Employment (MBIE) commissioned a literature review of NbS for flood management (NIWA. 2024). Applying the agreed UNEA definition of NbS, the literature review provided an up-to-date and in-depth analysis of the existing literature, case studies, and best practices related to the use of NbS for mitigating flood hazards. The literature review report provides a summary of the strengths, weaknesses, opportunities, and threats for NbS that can be used for flood hazard mitigation.

These themes are assessed in greater detail in this feasibility report for Te Hakapupu catchment.

2.2 TYPES OF NATURE BASED SOLUTIONS

As an umbrella concept, NbS include a number of related approaches that share a focus of protecting and enhancing the natural environment to address challenges, such as green infrastructure and water sensitive urban design (WSUD). Globally, NbS have been applied in response to a diversity of environmental challenges, including managing natural hazards and climate change adaptation, reducing greenhouse gas emissions (i.e. climate change mitigation), addressing biodiversity decline, or preventing land degradation.

[4] Note, definitions for Nature-based Solutions included in existing New Zealand planning frameworks predominantly reference NbS definitions from IUCN, the European Union, or WSUD guidance.

As illustrated in figure 4, NbS can be broadly classified under three core approaches of working with nature to address environmental challenges.

- **Protection, conservation, and restoration:** Protection and enhancement of natural environment features and ecosystems, such as river and flood plain naturalisation, coastal wetland, mangrove, and dune restoration, and control of browsing pest species.

- **Sustainable use:** The maintenance and sustainable use of natural environment values and ecosystems, such as native carbon forestry, community gardens, floodable recreation areas, regenerative agricultural practices.

- **Green infrastructure:** Development of issue-specific green infrastructure that creates natural environment features such as constructed wetlands, bioretention rain gardens and pervious paving in urban areas, and vegetated swales along flood prone waterways

Across a catchment, combining NbS with grey infrastructure can effectively maximize efficiency while minimizing economic trade-offs. Grey infrastructure can address critical planning challenges, such as enabling urban development within flood-prone areas by mitigating immediate risks from natural hazards. At the same time, NbS can complement these efforts by reducing the severity of hazards upstream and offering additional benefits, such as enhancing biodiversity and improving water quality, which grey infrastructure alone cannot achieve (TNC, 2023)

While a diversity of NbS approaches are available, careful consideration must be applied to ensure that NbS interventions are compatible with the natural landscape and existing land uses.

The type of NbS identified for testing in Te Hakapupu/Pleasant River Catchment were identified based on their ability to address the challenges associated with flood hazard, alongside their potential for enhancing the biodiversity values present in the catchment and ability to mitigate other environmental pressures, such as soil degradation and water quality decline.

Figure 3: Example of naturalisation of a waterway formerly contained in concrete channels as a method to manage the effects of extreme rainfall induced flooding. Source: Boffa Miskell Ltd.

Figure 4: Examples of the range of nature-based solutions that can be applied across a catchment. Image: Boffa Miskell Ltd.

2.3 THE BENEFITS OF NATURE-BASED SOLUTIONS

Healthy natural ecosystems act as the first line of defence against natural hazards, including flooding and associated hazards. When ecosystems are healthy, they buffer us from the impacts of natural hazards and increase our resilience to their effects (IUCN, 2020).

As shown in figure 5, NbS seek to protect, conserve, restore, and sustainably use natural ecosystems to address environmental challenges, such as flooding, while simultaneously contributing benefits for our environmental, social, economic, and cultural wellbeing. Through actions to establish or restore natural environment features, such as constructing wetland areas and replanting river riparian margins, NbS effectively manage flood hazards while enhancing the health of important ecosystems in a catchment.

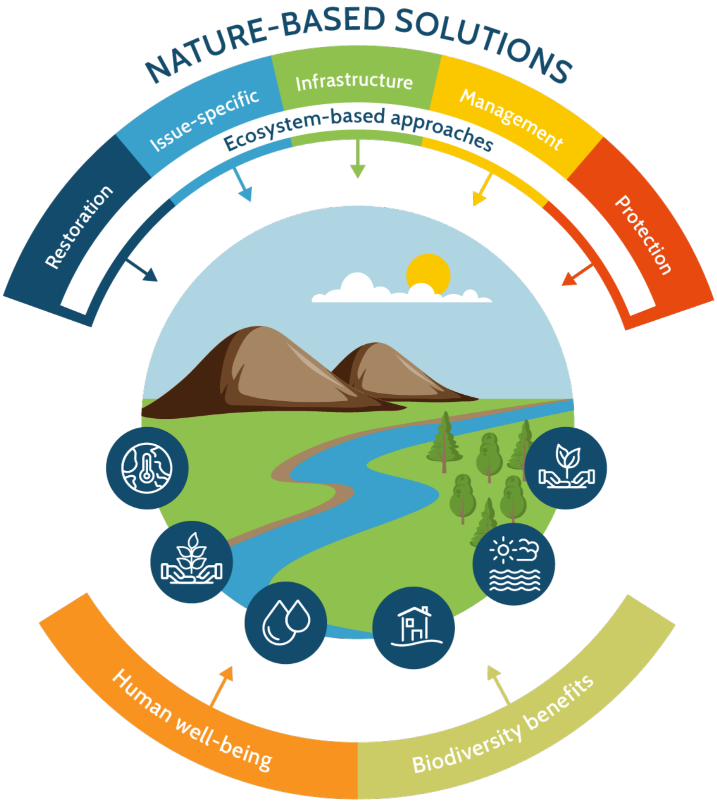


Figure 5: Diagram illustrating how Nature-based Solutions can result in benefits for human well-being and biodiversity. Source: IUCN, 2020

2.3.1 Flood hazard management

NbS are primarily designed as a response to an environmental challenge, such as flooding and associated hazards. NbS can act as practical additions or replacements for conventional 'grey' infrastructure to effectively mitigate and manage hazards across a landscape.[5] Whilst a historically tried and proven approach, in the face of climate change exacerbated flood hazards, 'grey' infrastructure approaches may face long-term challenges.

[5] **Grey infrastructure** refers to engineered structures such as dams, seawalls, or stormwater management pipes and drains.

Challenges include that grey infrastructure is often difficult and costly to adapt, maintenance costs increase as assets age, and they can negatively impact natural environment values through modifying the natural hydrology of a catchment (Climate Change Commission, 2024).

By contrast, NbS manage flood hazards by influencing the natural processes across a catchment to accommodate and redistribute water – changing how extreme rainfall is received by the environment and moves across the landscape.

These practices aim to restore and maintain the natural characteristics of a catchment's hydrology similar to those that existed pre-development.

2.3.2 Human wellbeing & social benefits

Table 1: Summary of human wellbeing and social benefits potentially gained from nature-based solutions. Adapted from More than Water – Assessing the Full Benefits of WSUD (Manaaki Whenua, 2019)

BENEFITS	SUMMARY
Provisioning / Mahika Kai	Traditional mahika kai sources in water bodies are abundant and carry a very low risk of human health effects from consumption.
Recreation	Water bodies are appealing for wide range of recreation, for instance having good water clarity, sandy bed sediments and limited levels of algal growth. Receiving water bodies are well suited to recreation, having a very low risk of human health effects from water contact due to excellent water quality.
Nature connection	Water bodies and green open spaces are celebrated as community assets and easily accessed, with stream and coastal margins in public ownership or easements, and well served by footpaths and accessways that allow views of the landscape and water in places.
Community resilience	Surface flooding is avoided or restricted to designated overland flow paths, flood storage basins and/or parks and reserves, allowing peak flows to spread out with low energy, limiting impact on private properties.
Supplementary water supply	Widespread harvesting and use of stormwater for potable and non-potable uses. Stormwater is detained in ponds/wetlands and is extracted for landscape irrigation during drought periods.

2.3.3 Biodiversity & environmental benefits

Table 2: Summary of biodiversity and environmental benefits potentially gained from nature-based solutions. Adapted from More than Water – Assessing the Full Benefits of WSUD (Manaaki Whenua, 2019)

BENEFITS	SUMMARY
More natural hydrological regime	Runoff volume, stream peak flows, time-to-peak, low flows, and flow variability are more similar to those in an undeveloped catchment than is the case with a conventional development approach
Better water quality	Concentrations of contaminants such as suspended sediments and nutrients in receiving water bodies (e.g. estuary wetland complex) are able to be processed and more similar to those in an undeveloped catchment than is the case with a conventional development approach
Better aquatic and riparian habitat quality	Stream channel geomorphology and bed substrate are more similar to those in an undeveloped catchment. Stream banks are stable and largely lined with diverse native riparian vegetation, providing shade and woody debris inputs to aquatic habitats
Better terrestrial habitat quality	The presence of significant areas of relatively undisturbed or rehabilitated natural vegetation provides high quality terrestrial habitat. Widespread green space is linked by vegetated corridors to maintain or restore a network of green corridors.
Drainage network and ecosystem connectivity	The natural drainage network is largely intact from its headwaters to the stream or river mouth, with few or no artificial barriers to fish passage and good habitat quality maintained throughout.
Natural Character	Characteristics of land, water bodies, and riparian margins are rehabilitated to largely the same as in undeveloped catchment, including the presence of significant undisturbed natural landforms, and improved channel form and sinuosity, water clarity, riparian and vegetation composition.
Carbon Sequestration and Mitigation	Widespread vegetation, especially trees and wetland plants, acts as significant sink of carbon, reducing overall land use emissions and contributing to climate change mitigation outcomes

2.3.4 Economic benefits

A healthy, biologically diverse environment offers substantial economic benefits. To maximize these, it is essential to evaluate the direct and indirect costs and benefits of NbS across their design, implementation, and maintenance phases.

Globally, NbS have the potential to reduce the intensity of climate hazards, such as flooding and coastal inundation, by 26%, with a potential cost saving from climate change impacts of USD 104 billion by 2030 and 393 billion by 2050 (WWF, 2022).

A recent report from WWF established that high-quality NbS can provide significant benefits to New Zealand's economic prosperity, with land-based environmental benefits, such as the provision of clean water and healthy soils, delivering benefits equivalent to 27% of New Zealand's GDP (WWF, 2024).

Furthermore, these natural environment values have been found to support employment, with approximately 1.2 billion jobs worldwide in sectors such as farming, fisheries, forestry, and tourism depending on the effective management and sustainability of healthy natural environments (WWF, 2020).

Implementing NbS to protect nature and achieve New Zealand's international biodiversity targets, under the Kunming-Montreal Global Biodiversity Framework, could save New Zealand an estimated $271.8 billion over the next 50-years (2025 – 2080). These savings stem from mitigating the impacts of nature decline and climate change while unlocking economic opportunities from a thriving natural environment (WWF 2024).

2.4 CHALLENGES & BARRIERS

Despite the significant opportunities NbS present, and as experienced by other NbS early adopters, their application within Otago and wider New Zealand faces a number of common challenges. Such challenges include economic viability of NbS, the ability for NbS to be applied at scale, a lack of national technical NbS guidance, standards and policies and misunderstanding about NbS, their purpose and value.

Economic viability of NbS

A key challenge that can impact the adoption and long-term viability of NbS are the economic challenges associated with private landowners changing land uses for NbS, from primary production land uses, such as farming and forestry, to natural ecosystems, such as wetlands. The economic viability of NbS, is impacted when landowners are unable to gain economic return from transitioning from productive land uses e.g farming and forestry to a natural ecosystem land use.

Ability to apply NbS at scale

If NbS are not made economically viable for landowners, their large-scale adoption and long-term use will likely remain limited. At present in New Zealand, limited funding, and financial incentives for NbS implementation and maintenance restricts their widespread use at scale required to address natural hazards, such as flooding and to bring other benefits.

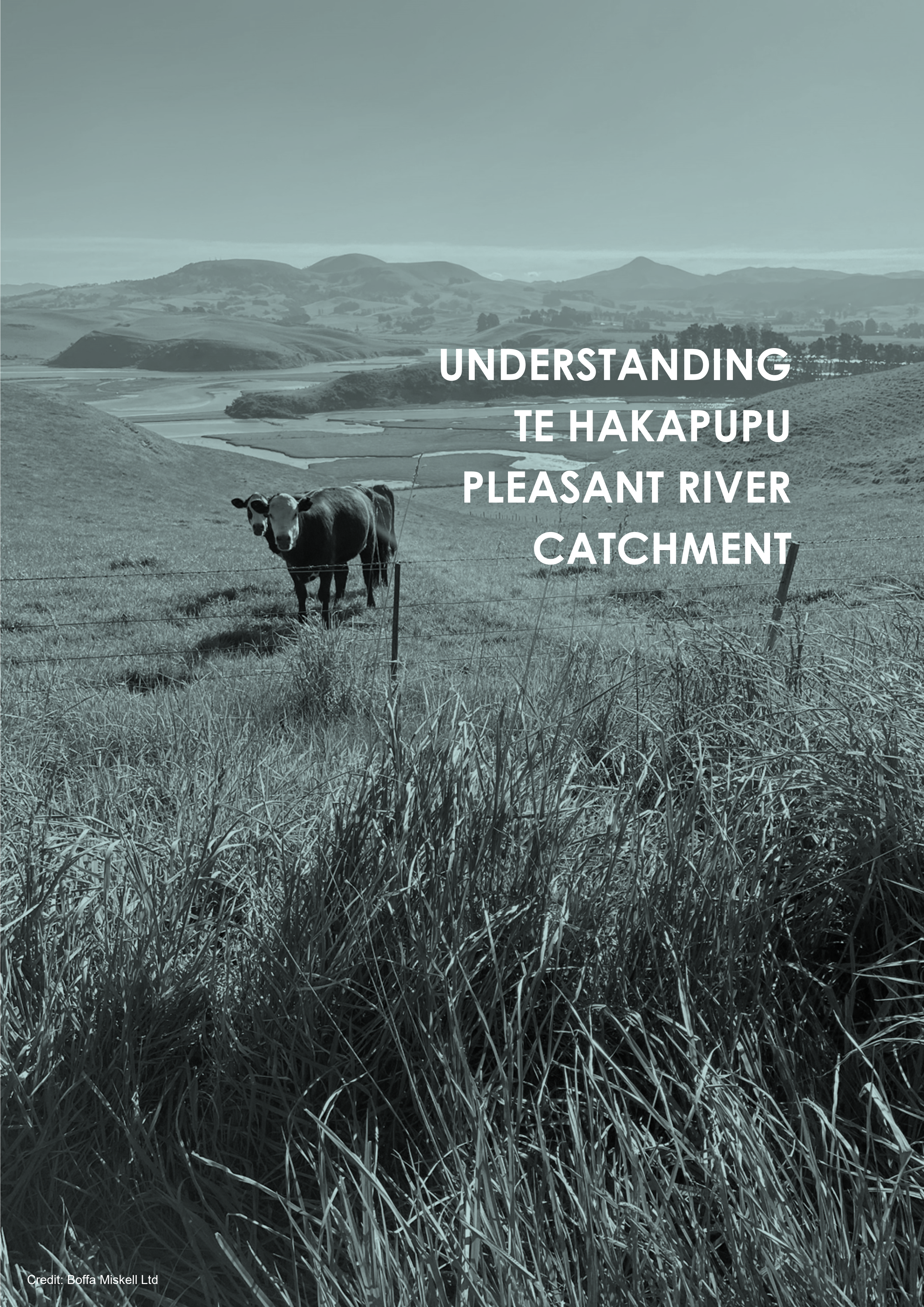
Where there is competition for use of land, including development pressures, the land available for NbS to function sufficiently can be constrained, further increasing the costs associated with the implementation of NbS. When presented with few economic incentives and competing land use pressures, achieving consensus between multiple landowners to implement NbS at large scales proves to be a challenge (NIWA, 2024).

Lack of a consistent technical NbS framework

Absence of comprehensive guidance and monitoring data leads to misuse or misinterpretation of NbS (UNEP, 2022). Without clear definitions and proper understanding, this may result in unintended adverse effects or failure to realise potential biodiversity benefits that could be gained.

While NbS can involve both natural and modified ecosystems, actions that degrade the overall integrity of natural ecosystems do not align with the NbS definition in the UNEA 5/5 Resolution or meet the criteria of IUCN's Global Standard for NbS, as they fail to provide environmental co-benefits (IUCN, 2024). For example, one of the common misconceptions is that actions designed exclusively for climate change mitigation, such as monoculture forest plantations are considered a nature-based solution.

As NbS continue to be adopted more frequently, there is a pressing need for greater clarity of what NbS entail, and what is required for them to be implemented successfully.



UNDERSTANDING TE HAKAPUPU PLEASANT RIVER CATCHMENT

Credit: Boffa Miskell Ltd

3. UNDERSTANDING TE HAKAPUPU/PLEASANT RIVER CATCHMENT

3.1 OVERVIEW OF CATCHMENT CHARACTERISTICS

The Te Hakapupu/Pleasant River catchment lies on the east coast of north Otago, between Waikouaiti and Palmerston, north of Dunedin, covering about 12,800 hectares of rural land. The catchment is sparsely populated, with around 200 residents. It is a highly modified landscape characterised by rural settlements, farming, and forestry land uses.

3.1.1 Waterways and wetlands

The catchment contains a network of tributaries, that feed into three main rivers and waterways (Te Hakapupu/Pleasant River, Owhakaoho/Trotters Creek and Watkin Creek) all of which confluence at the coast at Te Hakapupu/Pleasant River Estuary Wetland Complex (See Map 3: Waterways and Wetlands).

The catchment varies in altitude from 616m above sea-level (Hikaroroa/Mt Watkin) to sea-level. The main tributary, Te Hakapupu/Pleasant River, has a reasonably well entrenched gradient of 1 in 110 above State Highway 1 (SH1). While below SH1, the channel opens out onto the estuary.

The wetland complex is predominantly an estuarine system of about 84 hectares in size. It is the largest wetland in the North Otago Freshwater Management Unit (FMU). Estuarine wetlands such as this are one of the Naturally Uncommon Ecosystems in New Zealand, meaning historically rare. It is also classified as 'vulnerable' due to historic and ongoing loss in extent and decline in its ecological integrity (Holdaway et al., 2012).

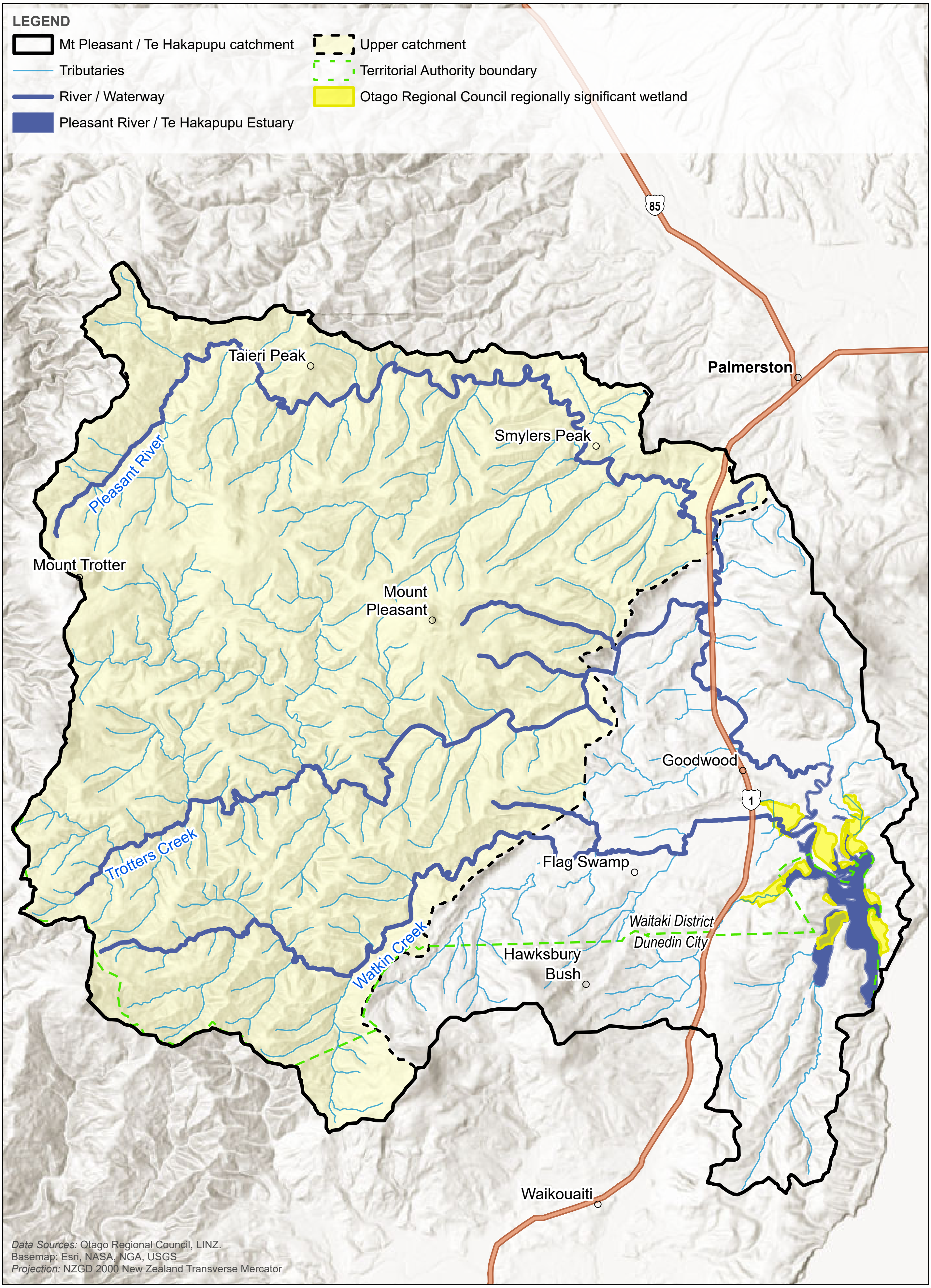
The wetland complex contains habitat for threatened and vulnerable freshwater and estuarine species, as well as providing recreational opportunities, and natural landscape character values. Additionally, mana whenua values are associated with the estuary wetland complex which supports mahika kai species, kaitiakitaka, mauri, and the practice and teaching of mātauraka Māori.

3.1.2 Landscape features

From the Te Hakapupu/Pleasant River estuary, the catchment rises to 616m elevation. The lower catchment is generally characterised as flat landscape with easy rolling hills, the upper catchment areas are dominated by more hilly terrain and steep slopes.

The upper catchment landscape contains six volcanic peaks, Mount Watkin (Hikaroroa), Mount McKenzie (Pakihiwitahi), Mount Trotter, Mount Royal (Te Ruatūpāku), Middle Mount, and Mount Pleasant. All peaks are identified as significant natural features in the Waitaki District Plan. Exotic forestry is a key feature of the upper catchment landscape.

See Appendix 5 for more information about the landscape context of Te Hakapupu/Pleasant River catchment.



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Waterways and Wetlands

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MAP 3

3.1.3 Ecosystems and habitats

At present, remnant indigenous ecosystems occur in small pockets across the catchment, with the estuary wetland complex containing valued indigenous plants, such as glasswort and sea primrose. In the upper catchment, small remnant areas of indigenous broadleaf forests, matagouri, coprosma, kōwhai scrub, and kānuka scrub are found. Collectively, these remnant indigenous forest and scrub areas cover approximately 1% of the catchment.

The estuary is identified as a Regionally Significant Wetland in the ORC Regional Plan, and as a Significant Natural Feature and an Area of Significant Nature Conservation Value under the Waitaki District Plan and as an area of significant biodiversity value in the Dunedin City Council 2nd Generation District Plan.

The estuary has a reduced size of approximately 2% of its historic extent due to drainage and reclamation (Leathwick *et al.,* 2010). State of the Environment monitoring of the estuary conducted by the ORC in 2022 has indicated that there are elevated nitrate and nutrient levels in the estuary. Additionally, sediment input, derived from natural and anthropogenic activities (farming and exotic forestry) in the catchment leads to enriched muddy sediments in the estuary (Forrest *et al,* 2022).

Built structures that impede salt marsh growth, such as causeways, flap gates and railway infrastructure, are common within the estuary wetland complex area. These structures have significantly altered estuary hydrology and disrupted the natural connectivity between the land and the sea, compromising the overall ecological health and ecosystem services of the estuary wetland complex (Ahikā Consulting Ltd, 2023).

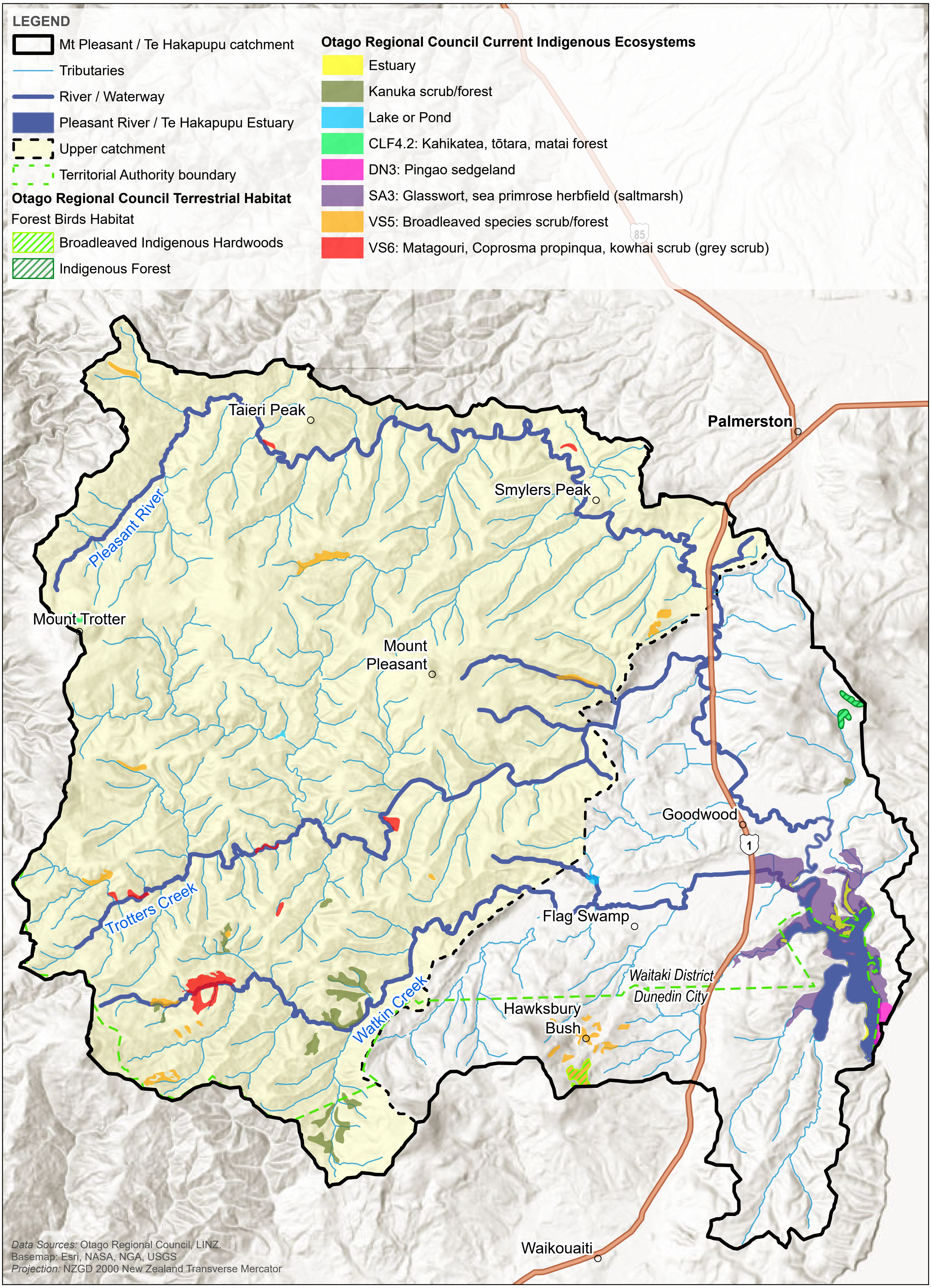
The catchment contains little formally protected conservation areas. These are mainly located at land surrounding the Pleasant River Sand Spit and the estuary mouth. Hawkesbury Bush represents the only moderately large QEII covenant in the catchment, covering 10 hectares of native forest remnants located near the southern extent of the catchment.

See Map 4 and Appendix 4 for more information about the biodiversity values identified within Te Hakapupu/Pleasant River catchment.

3.1.4 Land ownership and use

The land within the catchment is predominantly in private ownership, with nearly half being used for commercial exotic forestry. Plantation forestry land uses are located mainly in the steeper upper catchment area in the west of the catchment. Whilst a number of individual landowners undertake forestry activities as part of their farm businesses, four forestry companies (PF Olsen, Wenita, Ngāi Tahu Forestry, and Calder Stewart) oversee most of the forested area. The remaining land is used for farming, with small pockets of residential/lifestyle land near the coast. Pastoral farmland in the catchment is predominantly sheep and beef, with a smaller amount of dairy and deer farming. There are no arable farms within the catchment area.

Land use in Te Hakapupu/Pleasant River catchment is shown in Map 5



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Ecosystems and Habitat

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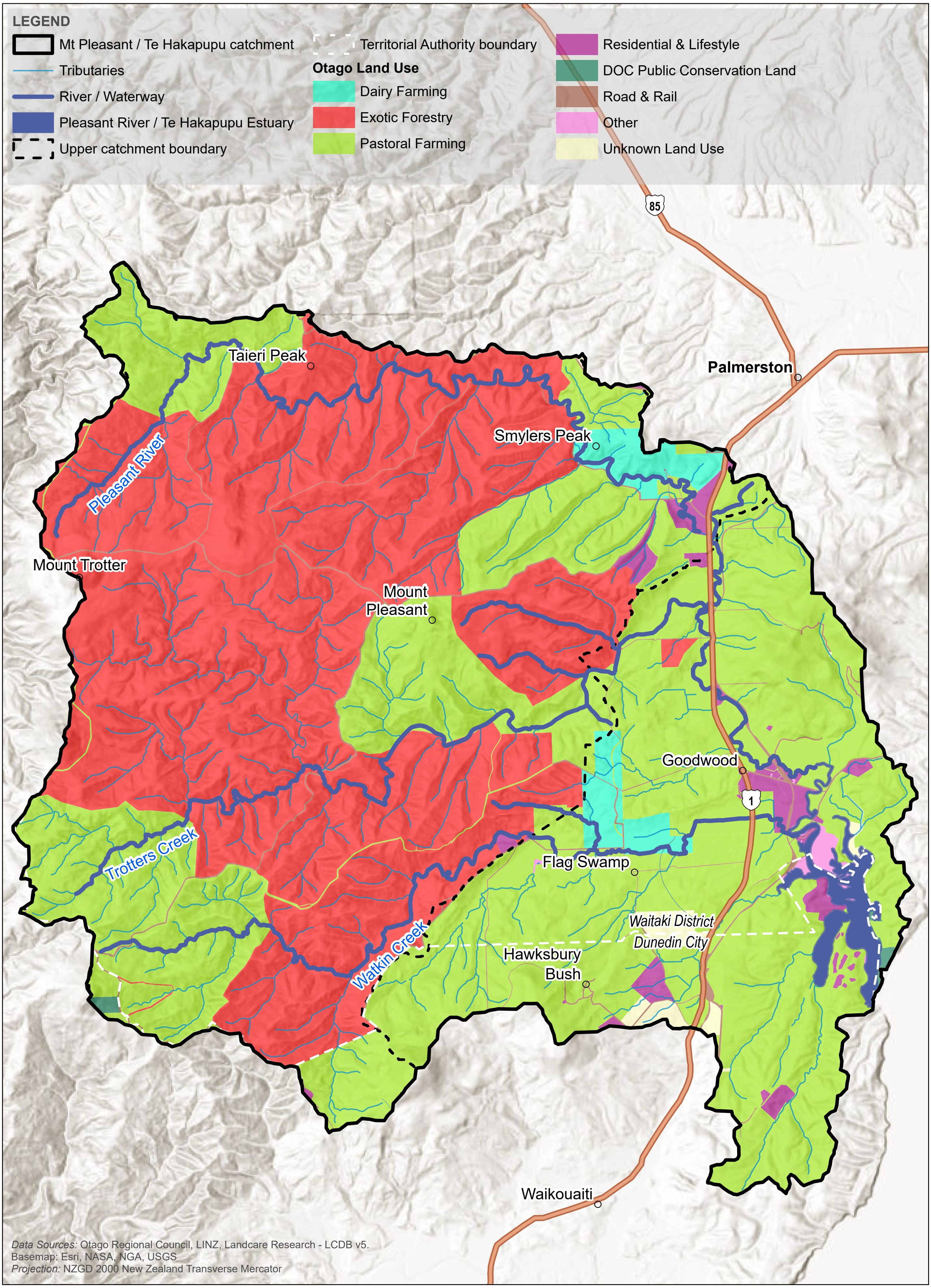
MAP 4



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Land Use

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MAP 5

3.1.5 Present day climate

The present day climate of Te Hakapupu/Pleasant River catchment is typical of coastal Otago, with annual mean temperatures ranging between 8-12°C. Summer mean temperatures range between 12-16°C and winter mean temperatures range between 6-8°C. Annual rainfall is comparatively low (compared to inland high elevation areas of the Otago Region), around 600-650mm, with the catchment sometimes becoming 'dry' by New Zealand standards during summer months, driven by higher evapotranspiration rates.

The East Otago area can also experience extreme high intensity rainfall events, typically occurring over a 12–72-hour period when a low-pressure zone is located to the east of the South Island. Historically, the average extreme rainfall depth received in the East Otago area is 166mm for a 100-year Annual Recurrence Interval (ARI) over a 24-hour period, and 95mm for a 10-year ARI over a 24-hour period, recorded at Palmerston (figure 6).[6]

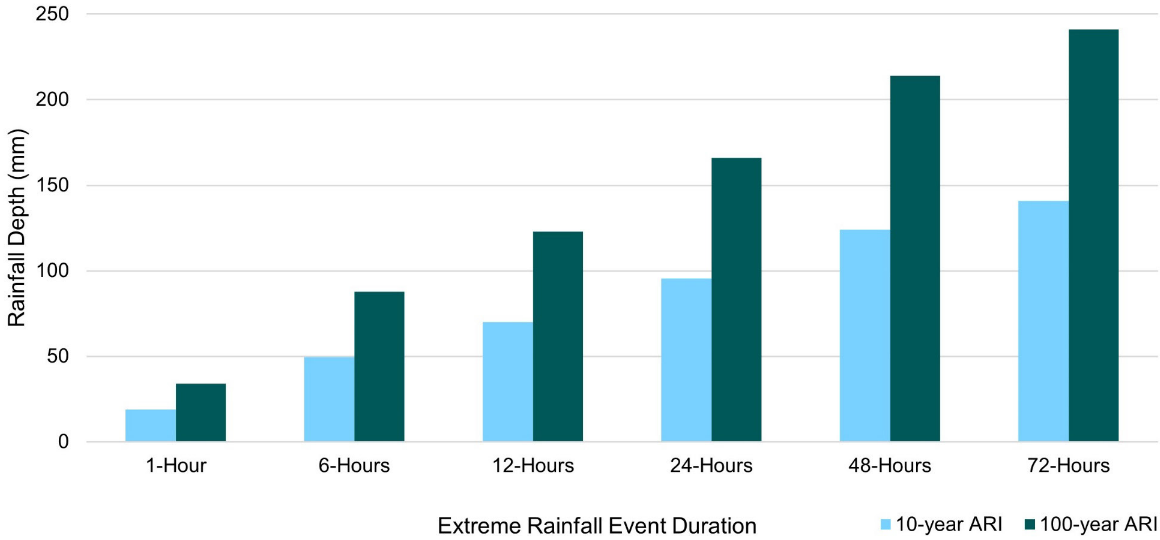

Figure 6: Historic 10-year ARI and 100-year ARI extreme rainfall event depths for 1-hour to 72-hour durations for the Palmerston area. Data sourced from Palmerston rain station, NIWA Cliflo

3.1.6 Flooding

In Te Hakapupu/Pleasant River catchment changes in land-use, land coverage, and catchment hydrology characteristics have increased the exposure to flooding and associated hazards within the catchment. This has included drainage of the large sections of the estuary wetland in the lower catchment and establishment, clearance of forest and scrub landcover for primary production lands in the mid and upper catchment, and later (in the 1990's) establishment of significant plantation forestry operations in the upper catchment.

[6] **Annual Recurrence Interval (ARI):** Extreme rainfall events are often considered in the context of their expected 'return period', known as an Average Recurrence Interval (ARI) (e.g. a 1-in-100-year rainfall event has an ARI 100). This does not mean that an ARI-100 rainfall event will happen regularly every 100-years or will only occur once in 100-years; it refers to the probability of the event occurring in any one year (i.e. 1%)

Significant recorded flood events in the catchment include:

- October 1947 – The Palmerston railyards were flooded to a depth of 0.9m and the main road was flooded in several locations.
- October 1968 – The floodwaters in the branch above Goodwood reached very high levels, flooding at least three houses and all of the Flag Swamp adjacent to Watkin Creek. The severity of flood inundation was attributed to debris build up on the rail bridge.
- July 2022 – A heavy rainfall event across coastal Otago areas, with some areas receiving between 110-150mm of rainfall, forcing the closure of SH1 between Dunedin and Palmerston, shown in figure 7.
- October 2024 – A heavy rainfall event across coastal Otago areas, with some areas receiving between 160-180mm of rainfall, causing numerous land slips along transport routes and forcing the closure of SH1.

While rainfall induced flooding are fundamentally driven by meteorological processes, it is the interaction between the receiving environment and the rainfall event that determines whether the process results in a flood.

Figure 7: Flooding at Big Kuri Creek, north of Hampden, experienced during the July 2022 East and North Otago extreme rainfall event. Source: NZTA

3.1.7 Water quality

Monitoring of water quality has been undertaken since 2021 as part of the Toitū te Hakapupu Pleasant River Catchment Restoration Project to establish baseline information for the catchment and provide a greater understanding of the source and state of water quality issues experienced.

With the geology of the catchment dominated by schist (38%), sandstone (28%), and siltstone (22%), a large proportion of the catchment is vulnerable to erosion. This leads to the deposition of sediment into the Hakapupu waterways and estuary. These sediment inputs have been raised as a significant issue for water quality within the catchment, with the health of the estuary adversely impacted by sedimentation and nutrient runoff.

Streambank and subsoil erosion are the primary sources of sediment depositing in the waterways, accounting for more than 80% of sediment deposited at most sampled sites. At the catchment outlets, streambank erosion accounted for as much as 98% of deposited sediment (Swales *et al,* 2023).

Figure 8: Suspended sediments being transported within Te Hakapupu / Pleasant River. Source: Peak Geospatial

Following forestry harvesting in Owhakaoho/Trotters Creek sub-catchment, the Owhakaoho/Trotters Creek was observed, contributing a large portion of the long-term suspended sediment loads (~77%) being discharged from the Hakapupu catchment (Swales et al, 2023).

With a significant amount of land use within the Owhakaoho/Trotters Creek sub-catchment being drystock pasture, and exotic production forestry activities increasing in the upper reaches, the disturbance of vegetation cover during a forestry harvest and replanting will likely exacerbate soil erosion in this area (Ahikā Consulting Ltd, 2023). It is likely that other forested sub-catchments would contribute similar if they were harvested as well.

With exotic production forestry being the dominant land use within the catchment, the land use sources of recent sedimentation in waterways suggest that harvest areas have the capability to generate much higher sedimentation than pastoral areas.

Specific proportional yields of topsoil from harvest areas are likely approximately 69 times higher than from pastoral farming crops and activities (Swales *et al,* 2023).

While this NbS Feasibility Study is focused on evaluating solutions for the management of flood hazards, considerations of sediment management are required as part of NbS evaluation to mitigate the effects of sediment during flood events, including reduced optical water quality (i.e., visual clarity, light penetration) and smothering of river floor ecosystems.

3.2 IMPACTS OF CLIMATE CHANGE ON THE CATCHMENT

3.2.1 Temperature

Consistent with climate change projections for coastal Otago, mean annual temperatures are projected to continue to increase over the coming decades under all climate change scenarios, warming by 1.5 – 2.5°C by 2090. This increasing mean temperature will cause an additional increase the number of 'hot days' (>30°C) experienced in the catchment annually and reduce the number of 'frost days' (<0°C) (Macara et al, 2019).

3.2.2 Rainfall

Mean annual rainfall in the catchment is projected to increase under all climate change scenarios, with increases of up to 10-15% in mean annual rainfall expected by 2090 (under RCP 8.5).[7] The greatest mean rainfall increases likely experienced during winter (20-25%), with more moderate increases expected during summer (0-5%).

3.2.3 Sea level rise and coastal inundation

Relative sea-level rise is projected to occur in the coastal areas of the catchment in line with national sea-level rise rates, with minor vertical land movement (0.7± 2.2mm/year) at the estuary mouth, slightly moderating the relative effects experienced locally. 0.21m of relative sea-level rise is projected by 2050 and 0.74m by 2100 (under scenario SSP5-8.5 50th percentile). Consequently, the Te Hakapupu/Pleasant River estuary wetland complex is highly likely to be exposed to increasing salinity stress and from the effects of more frequent and intense coastal storm surges flooding further inland areas.

Areas at exposure to the future effects of coastal inundation during storm surge events include properties currently adjacent to the existing estuary as shown in flooding zones / hazard zones on Map 6.

3.2.4 Extreme rainfall events

A warmer atmosphere can hold more moisture, therefore extreme rainfall events are projected to increase in frequency and intensity with continued global warming. Following national trends, extreme rainfall events are projected to increase within the catchment in the coming decades.

Under best-case (RCP 2.6), mid-range (RCP 4.5), and hot-house (RCP 8.5) climate change scenarios, extreme rainfall events in the catchment are projected to increase in the coming decades, with the depth extreme rainfall expected to be more severe with higher levels of global warming. This change has the dual effect of increasing the physical depth of rainfall experienced during an extreme rainfall event and increasing the frequency of historic extreme rainfall events reoccurring.

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[7] **Representative Concentration Pathways (RCPs):** Future climate change projections are considered under four emission scenarios, called Representative Concentration Pathways (RCPs) by the IPCC, based on future greenhouse gas concentrations, determined by economic, political and social developments during the 21st century. RCP8.5 is a 'business as usual' scenario with greenhouse gas emissions continuing at current rates

For example, under RCP 8.5 climate change scenario:

- A 100-year ARI 24-hour extreme rainfall event is projected to increase in depth from 166mm to 203mm by 2090 (i.e. increase in rainfall intensity) (Figure 6)
- The 166mm of rainfall historically expected during a 100-year ARI 24-hour event, is projected to be received during a 40-year ARI 24-hour event by 2090 (i.e. increase in the perceived frequency of historic events) (Figure 10)

The graph displayed in Figure 9 shows the projected increase in extreme rainfall depths under a hot-house (RCP 8.5) climate change scenario.

In the context of past extreme rainfall events experienced within the catchment, under a hot-house (RCP 8.5) climate change scenario, the annual reoccurrence interval of an extreme rainfall event, similar in magnitude to the flooding events of July 2022, would likely be approximately 10-years (i.e. 10% chance of occurring each year) by 2090 (NIWA HIRDS v4).

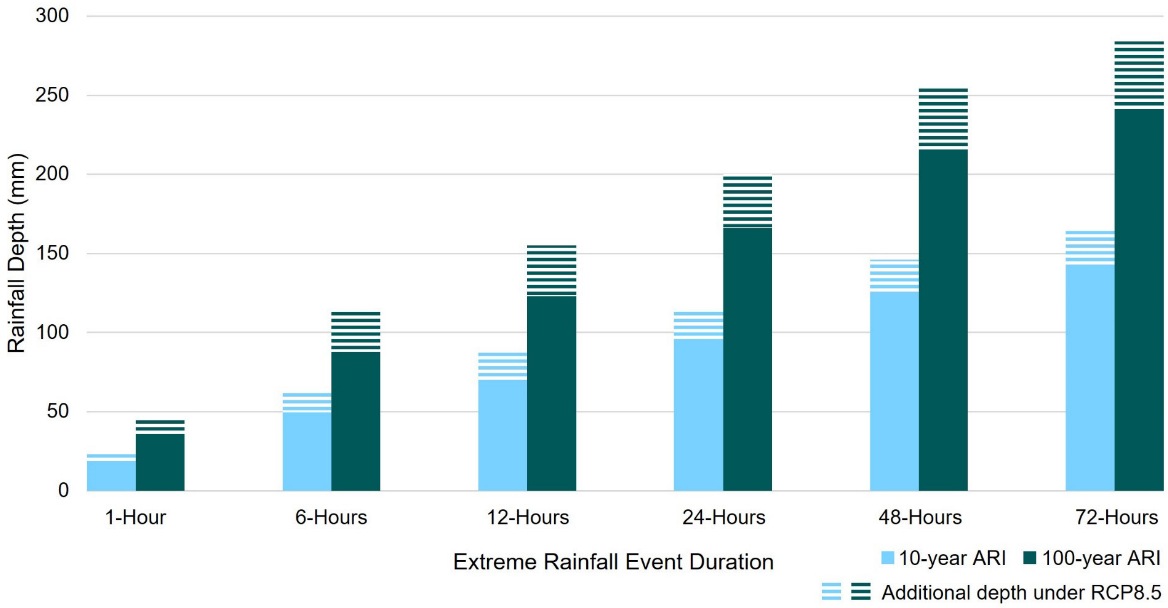
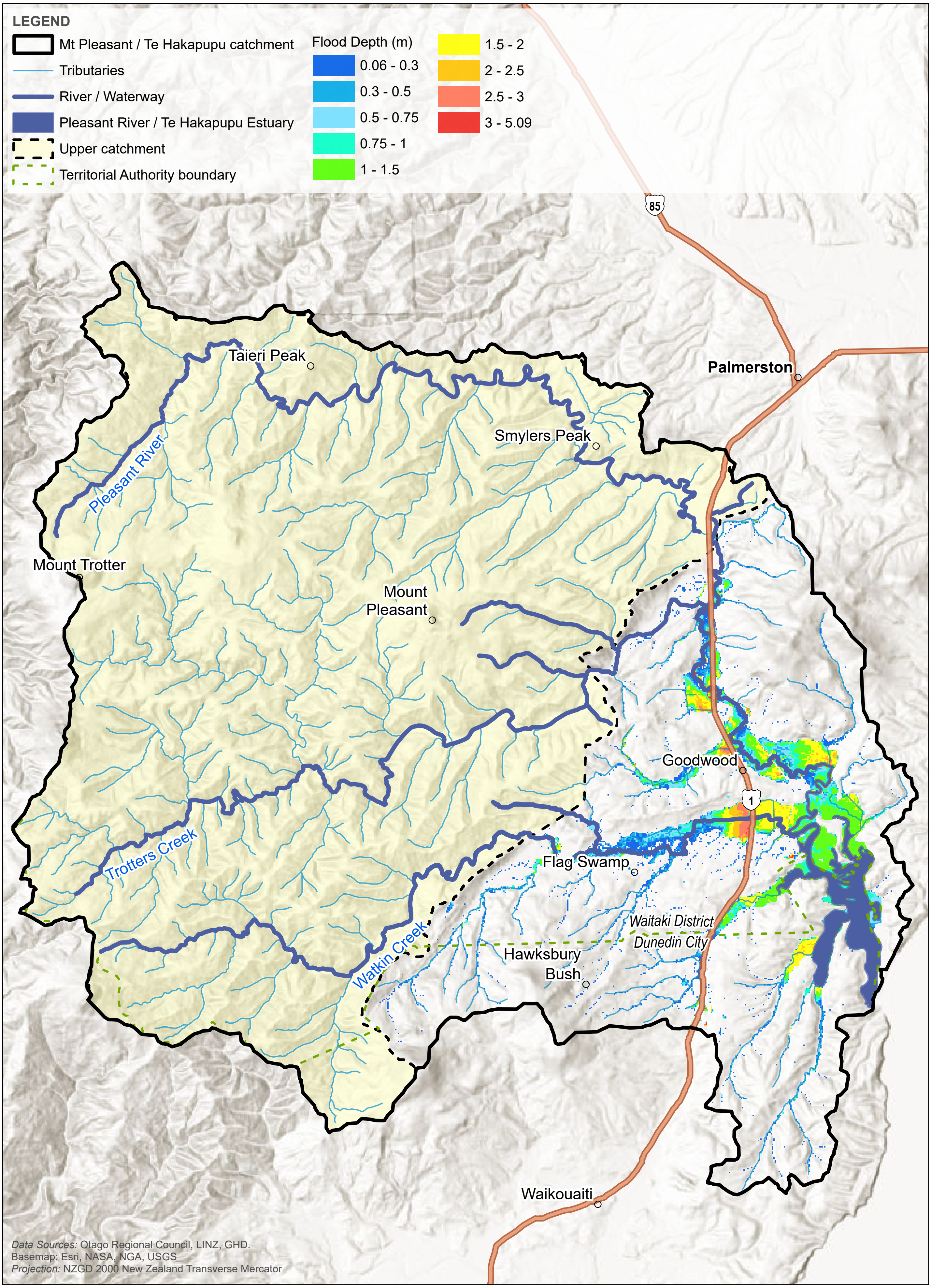


Figure 9: The projected additional rainfall depth (stripe bars) expected under climate change for historic 10-year ARI and 100-year ARI extreme rainfall event depths for 1-hour to 72-hour durations (solid bars). Data sourced from NIWA HIRDs database for climate change scenario RCP 8.5 at 2090

3.2.5 Extreme rainfall event induced flooding

Based on the Rapid Flood Hazard Modelling (RHFM) of the catchment, extreme rainfall event induced flooding is expected to exhibit similar behaviours to that observed during previous flood events.

The modelled flood characteristics that would occur in the catchment during a 100-year ARI 24-hour extreme rainfall event, under RCP 8.5, are shown in Map 6 (Flood Depth) and Map 7 (Flood Velocity). During extreme rainfall events, flood waters are modelled to flow down the upper and mid-catchment relatively swiftly, slowing as they approach the northern and western extent of the existing Te Hakapupu/Pleasant River estuary wetland complex. Surface flooding would commonly range from 0.5m to over 2.0m and is likely to occur in areas bordering the existing wetland, where lands have been historically drained and reclaimed for agricultural purposes.



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Flood Depth

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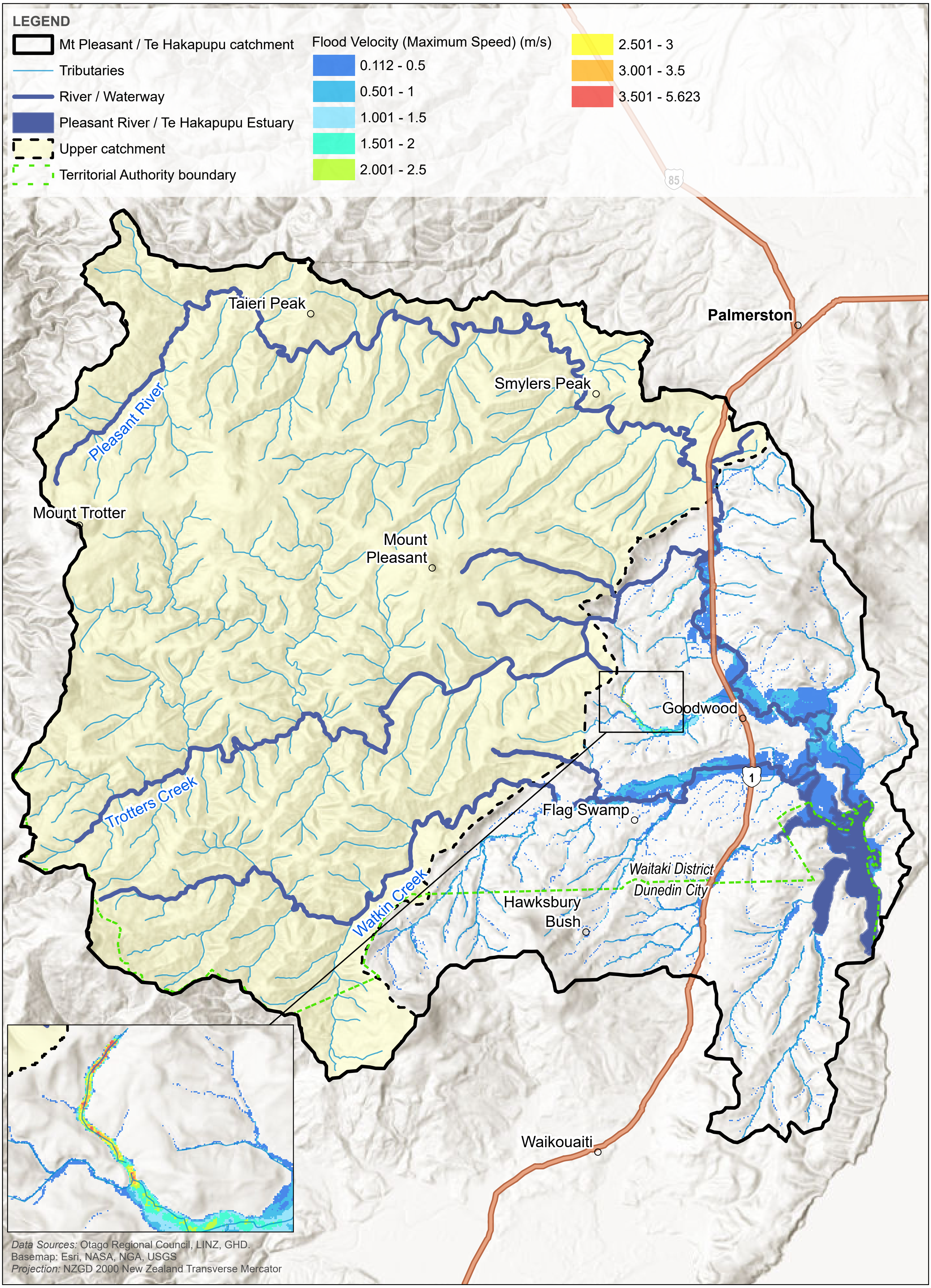
MAP 6



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Flood Velocity

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MAP 7

3.3 STATUTORY & POLICY CONTEXT

To further assist with understanding the potential application of NbS within the catchment and across the wider Otago Region, an initial high-level review of the regional and local statutory and policy context was undertaken. This helps to identify any consenting and/or regulatory opportunities and challenges that would need to be considered. For more information on the statutory and policy context applicable to the use of NbS in Te Hakapupu/Pleasant River Catchment, see Appendix 6 or visit the ORC website.

3.3.1 Regional plans

The Te Hakapupu/Pleasant River catchment is within the Otago region and therefore is subject to the provisions of the Otago Regional Policy Statement 2019 (RPS), Otago Regional Policy Statement 2021 (pORPS) and the Otago Regional Plan: Water 2004 (ORPW).

3.3.2 Otago Regional Policy Statement

The Otago Regional Policy Statement 2019 (ORPS) and its update, the proposed Otago Regional Policy Statement 2021 (pORPS), provide the strategic framework for managing natural and physical resources across the Otago region.

The ORPS sets out objectives and policies to address key environmental issues, including freshwater management, biodiversity, climate change, and sustainable development. The pORPS, currently under development, builds on the ORPS by refining and updating policies to align with new national directives, such as the National Policy Statement for Freshwater Management 2020 (NPS-FM). The policies reflect a strong commitment to Te Mana o Te Wai, and highlight the relationship of Kai Tahu with water, prioritising the importance of the health and well-being of water bodies to ecosystems and communities.

The ORPS and the pORPS enable the integration of Nature-based Solutions (NbS) into freshwater management by promoting approaches like wetland restoration, riparian planting, and natural flood management to address environmental challenges such as sedimentation, nutrient runoff, and biodiversity loss.

3.3.3 Otago Regional Water Plan

The Otago Regional Plan: Water 2004 (ORPW) is currently the primary regulatory regional document for managing activities affecting freshwater in Otago. A replacement draft Land and Water Regional Plan (LWRP) for the Otago region has been developed but as of January 2025 isn't operative.

Rules in the ORPW that are particularly relevant to the NbS include those that relate to:

- The take, use and management of water, and the management of discharges.
- Land use on lake or riverbeds, or within Regionally Significant Wetlands, specifically:
  - Alternation of the bed of a river or a Regionally Significant Wetland.
  - The introduction or planting of vegetation; and
  - The removal of vegetation
- Other land use activities including structures on the margins of lakes and rivers.

3.3.3 North Otago Freshwater Management Unit

The North Otago Freshwater Management Unit (FMU) is a defined area under the proposed ORPS (pORPS), and the draft Land and Water Regional Plan (LWRP). It serves as a framework for sustainable freshwater management, with objectives tailored to environmental, cultural, and community needs. Te Hakapupu/Pleasant River catchment is within the North Otago FMU.

Figure 10: North Otago Freshwater Management Unit (FMU) (Source Otago Regional Council)

The proposed vision for the North Otago FMU by 2050 is summarised below:

I. **Freshwater Management**:

- Freshwater resources are managed in alignment with Te Mana o te Wai, ensuring that the health and well-being of water bodies are prioritised.
- Acknowledges that the Waitaki River is influenced by catchment areas within the neighbouring Canterbury region.

II. **Ecosystem Health**:

- Healthy riparian margins, wetlands, estuaries, and lagoons are restored and maintained, supporting vibrant indigenous habitats, and enhancing downstream coastal ecosystems.

III. **Sustainable and Resilient Practices**:

- o Encourages innovative and sustainable land and water management practices to support food production and improve resilience to the effects of climate change.

As currently drafted, the North Otago FMU provides an indication of the ORC's intended approach to freshwater management in Te Hakapupu/Pleasant River catchment and a practical framework for incorporating NbS into freshwater management practices by promoting initiatives such as wetland restoration, riparian planting, and the use of natural processes to improve water quality.

3.3.4 District Plans

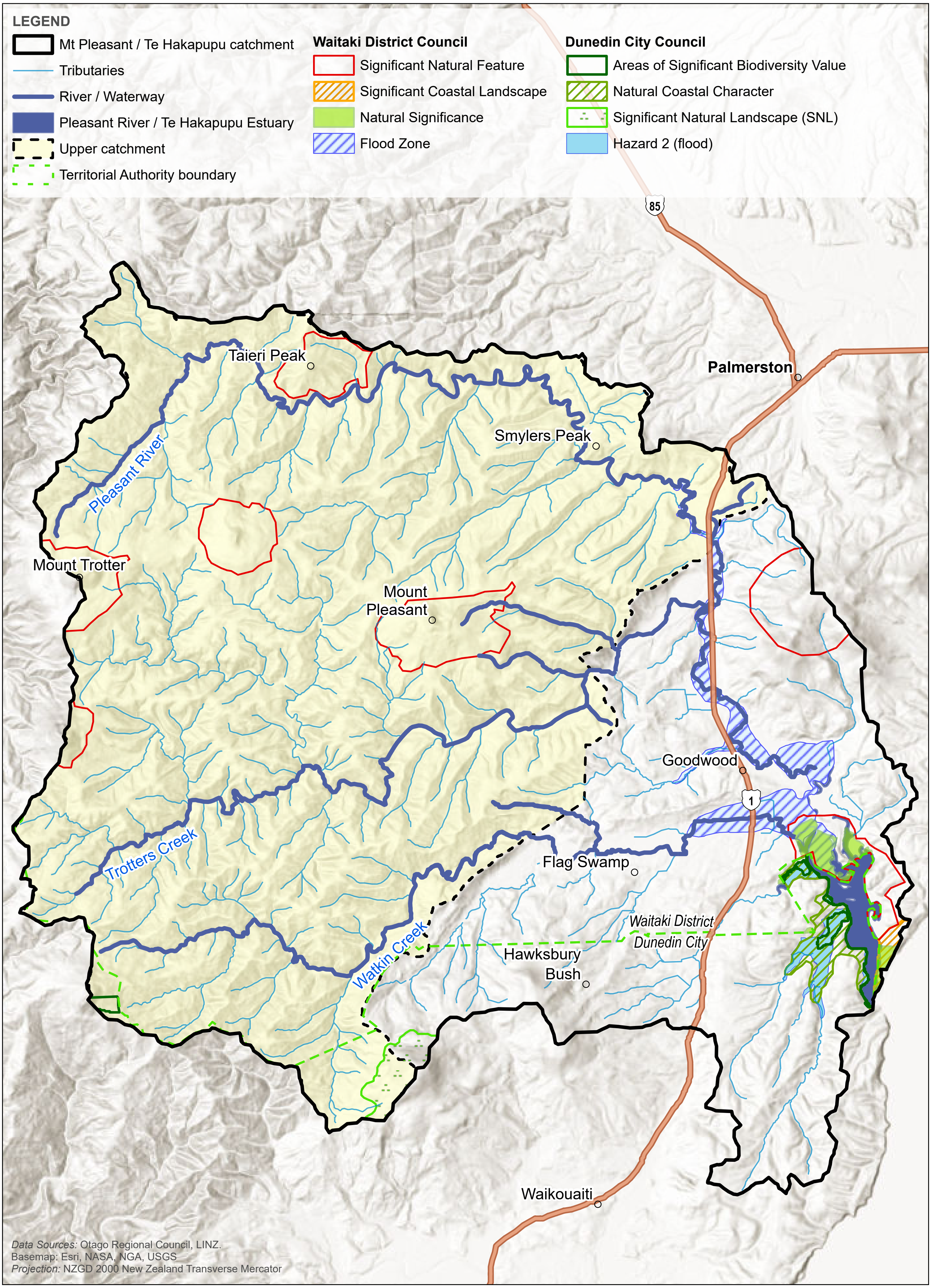
Te Hakapupu/Pleasant River catchment is mostly within the jurisdiction of the Waitaki District Council, apart from an area to the south of the estuary and part of Mt Watkin that fall in the jurisdiction of the Dunedin City Council.

The Waitaki District Plan and the Dunedin 2nd Generation District Plan are therefore the relevant district plans.

Within the Waitaki District, the catchment is largely within the rural zone, with some inland areas within the 'rural scenic' zone. Catchment areas within the Dunedin District Plan are also largely within the rural zone, except for a small rural residential area to the south of the Te Hakapupu/Pleasant River estuary. Both the Dunedin District Plan and the Waitaki District Plan identifies the estuary and surrounding wetland as areas of natural significance, with significant coastal and natural landscapes and features. The estuary and wetlands are also identified as flood hazard zones.

3.3.5 Kāi Tahu ki Otago Natural Resources Management Plan 2005

Policies in the Kāi Tahu ki Otago Natural Resources Management Plan 2005 (NRMP) express the cultural importance of water to Kāi Tahu and the importance of protecting and restoring the mauri of all water. The policies cover the protection and enhancement of existing wetlands as well as the reinstatement of wetlands that have been neglected.



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Dunedin City and Waitaki District Plans

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MAP 8

Credit: Peak Geospatial

4. WHICH NATURE BASED SOLUTIONS ARE MOST SUITED IN THE CATCHMENT?

To assess how feasible the use of NbS are for the management of flooding and associated hazards in Te Hakapupu/Pleasant River catchment, three catchment specific NbS interventions were developed. With reference to the different types of NbS for flood management assessed in the recent NIWA literature review (NIWA, 2024), NbS interventions were considered for upper, middle, and lower catchment locations.

The three NbS considered most suited to the catchments environmental, social, and economic context are:

- Landcover management
- River and stream naturalisation
- Wetland enhancement and construction

These three NbS were developed based upon NbS best practice insights gathered through literature review and SWOT analysis discussions, hydrology modelling of the catchment during flood events, and the catchment's specific environmental characteristics.

Whilst targeted towards the management of how flood events are modelled to behave in the catchment, the NbS also seek to acknowledge the wider environmental challenges present in the catchment. These include the water quality challenges associated with streambank erosion and sedimentation, and the projected effects of sea-level rise and coastal storm surge inundation.

Additionally, the three NbS were developed with reference to the potential nature-based opportunities possible in the catchment. With reference to the Toitū Te Hakapupu Catchment Action Plan (CAP) (Ahikā, 2023), the NbS seek to contribute to the identified catchment restoration values. These include the enhancement of the natural functioning of the highly valued estuary wetland complex, with a focus on mahika kai and taonga species.

NbS interventions, such as bioretention systems, were not tested within the catchment. Whist contributing to flood management outcomes, these interventions were deemed impractical given the large scale and water quality pressures experienced in the catchment. Other related interventions, such as sedimentation ponds, were not considered in this feasibility study as they do not meet the definition of benefit requirements of NbS.

The below section describes the key characteristic of the three types of NbS that are considered in this feasibility study and outlines how they could conceptually be applied to the catchment environment. The outcomes of how the NbS were tested to performed in the catchment is detailed in section 5.

4.1 LANDCOVER MANAGEMENT

4.1.1 What is landcover management?

Landcover management is the practice of gradually transitioning areas of exposed clear-fell exotic plantation forestry to permanent indigenous forests work to manage flood hazards. This practice helps to moderate water yield and flows within a catchment, whilst avoiding the 'window of vulnerability' prompted by harvest cycles.

The "window of vulnerability" is a high-risk period that lasts for about eight years following the harvesting of a forest. During this time, the newly replanted trees have not yet grown enough to develop a full canopy or strong root systems capable of stabilising the soil and preventing sediment loss. Extreme rainfall events often increase the risk of sediment loss and flooding. Without tree cover and strong roots to hold the soil, more water flows downhill, carrying fine sediments and woody debris into lower areas.

Within Te Hakapupu/Pleasant River catchment, exotic plantation forestry is the most widespread single land use (~49%), predominantly situated in the steeper upper catchment. During an extreme rainfall event, sediment washing into waterways presents one of the greatest flood-related risks in the catchment. During flood events, sediment deposited in the riverbed, reduces the volumetric capacity of waterways. Sediment becoming dislodged from the riverbed and being washed down during floods is leading to sediment inundation of lower catchment freshwater and estuarine habitats.

These hazards associated with flooding are likely to be exacerbated during forestry harvest and replanting. Two major 'pulses' of forestry harvest are expected in the catchment over the coming decades (Map 10):

- The first harvest pulse occurring between present-day and 2028, covering approximately 33% of the catchment forestry estate.
- The second harvest pulse occurring from 2042 to 2049 covering approximately 40% of the catchment forestry estate.

Accordingly, the land exposed during the projected 'windows of vulnerability' is approximately 1,500 ha each year between 2024 – 2032, then larger again from 2042, to peak at over 2,500 ha per year (Ahikā, 2024).

4.1.2 How can landcover management work as a NbS?

Landcover management in Te Hakapupu/Pleasant River catchment will seek to restore and expand existing pockets of remnant indigenous forest, towards the gradual transition of large areas to permanent indigenous forest in vulnerable upper sub-catchment locations. Upper sub-catchment areas are shown in Map 9. With reference to the remnant indigenous forest ecosystems identified in Map 4, these areas will be prioritised for targeted pest control, maintenance, and planting to grow the extent of these areas and support natural regeneration.

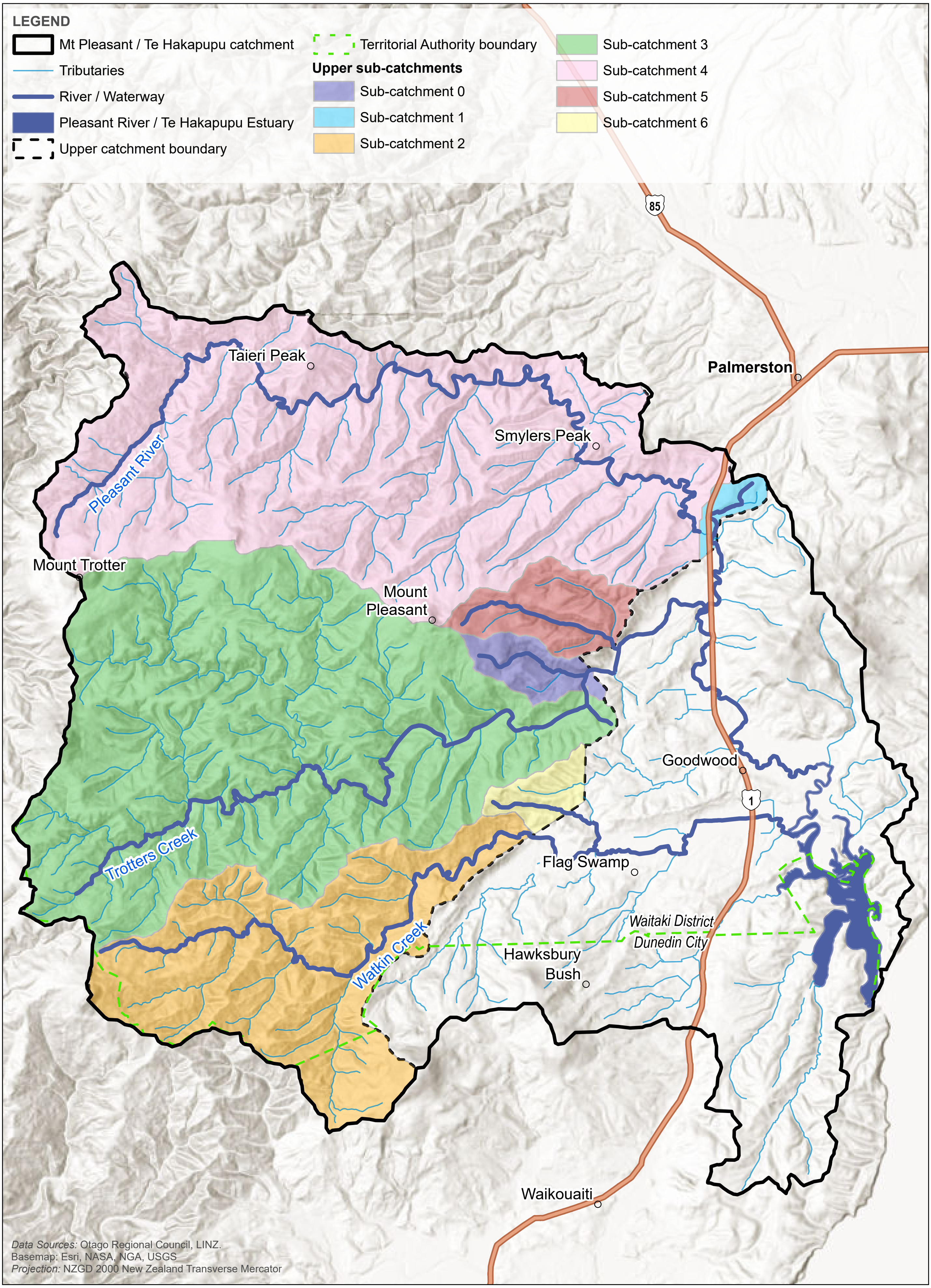
This approach will manage the impacts of flooding and associated hazards in the catchment through restoring and permanently retaining upper catchment forested land cover in vulnerable areas (e.g. on erosion prone slopes and in vicinity of waterways).

With the effects of climate change projected to increase the frequency and intensity of extreme rainfall events across Otago, this NbS would avoid exacerbating an already significant flood-related risk by eliminating the reoccurring ‘windows of vulnerability’ over future generations. By restoring indigenous forest across large areas and permanently retaining forested land coverage, the landcover management approach aims to safeguard the hydrology of the upper catchment to effectively buffer against the effects of extreme rainfall events

Plantation forestry within the Hakapupu Catchment is predominately contained within the upper catchment. Presently, there are 23 individual owners, of which four main forestry companies manage the vast majority of the planted area (Calder Stewart, Ngāi Tahu, PF Olsen, and Wenita). Aligning with existing harvest projections and replanting timeframes, this approach would require a long-term transition of upper catchment areas.[8]

Figure 11: Indigenous remnant forest area within pine forestry. Source: Pure Advantage

[8] While coupe harvest systems are being considered through the Te Hakapupu Forestry Action Plan as a practical solution to mitigate risks associated with harvest and replanting, this approach is not considered a NbS and is therefore excluded from this NbS feasibility study.



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

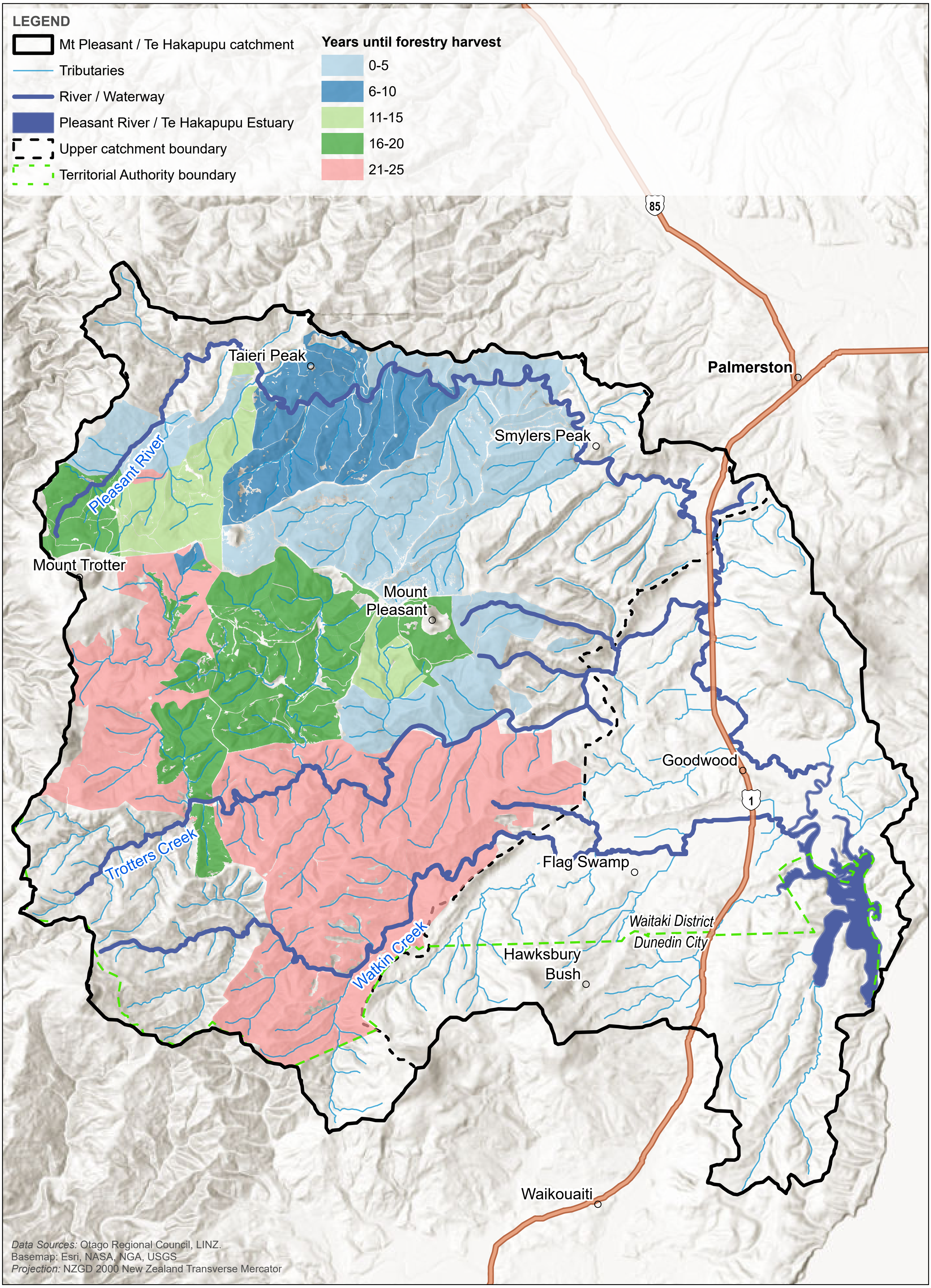
Catchment Map

Date: 06 December 2024 | Revision: 0

Plan prepared for Otago Regional Council by Boffa Miskell Limited

Project Manager: Rachael.Eaton@boffamiskell.co.nz | Drawn: LJa | Checked: SPa

MAP 9



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PLEASANT RIVER / TE HAKAPUPU CATCHMENT NATURE-BASED SOLUTIONS

Forestry Harvest Timing

Date: 05 December 2024 | Revision: 0

Plan prepared for Otago Regional Council by Boffa Miskell Limited

Project Manager: Rachael.Eaton@boffamiskell.co.nz | Drawn: LJa | Checked: SPa

MAP 10

4.2 RIVER & STREAM NATURALISATION

4.2.1 What is river and stream naturalisation?

River and stream naturalisation, includes:

- restoration of riparian vegetation (riparian buffers)
- 'making room for the river'
- reconnecting isolated or drained off-stream wetland areas
- works to mitigate flood hazards through intercepting contaminants entering the waterway during extreme rainfall events
- slowing peak flows
- stabilising banks to reduce erosion

Riparian buffers provide room for the natural dynamics of a waterway to function during extreme rainfall events. This includes accommodating the rise and fall of water levels, helping to slow down the velocity of peak flows, increasing water retention and infiltration, and reducing streambank erosion and thus the potential effects of associated downstream flood impacts (e.g., sediment inundation and water contamination).

Whilst channelisation of waterways is not as severe as other more hydraulicly modified catchments in the Otago Region, the main tributaries of the Te Hakapupu / Pleasant River, Watkin Creek, and parts of Owhakaoho / Trotters Creek in the mid-catchment currently have relatively bare, unvegetated riparian margins. As a result, these unvegetated, well entrenched channels facilitate fast peak flood flow velocities up to 5 m/s during an extreme rainfall event. With little riparian vegetation to protect stream banks, stream bank erosion accounts for as much as 98% of deposited sediment at the catchment outlets to the Hakapupu Pleasant River Estuary Wetland Complex (Swales *et al,* 2023).

Te Toitū Te Hakapupu partnership project has undertaken considerable restoration of riparian areas in the lower catchment in recent years, including 27km of fencing and almost 68,000 plantings. However, large sections of waterways throughout the Hakapupu catchment remain 'denaturalised' as farming land uses has constrained natural waterways and riparian corridors into more uniform, deeper channels to improve farm management.

Additionally, as waterways have become increasingly 'denaturalised', small adjoining tributaries and off-stream wetland areas that provide important spawning habitat for freshwater species, and help retain water during dry periods, have become piped or cut off from the main channel. Consequently, during extreme rainfall events, flood waters tend to flow at faster velocities through the main tributaries of Te Hakapupu / Pleasant River, Owhakaoho / Trotters Creek, and Watkin Creek. This causes surface flooding of low-lying areas in the lower catchment and allows for the rapid transport of sediment and other contaminants from the upper catchment into the vulnerable estuary wetland complex.

4.2.2 How can river and stream naturalisation work as a NbS?

Undertaking river and stream naturalisation, in the catchment, such as along Te Hakapupu/Pleasant River, Owhakaoho/Trotters Creek, and Watkin Creek, aims to reduce flooding hazards by restoring the natural hydrodynamics of the waterways. Naturalisation helps to slow down peak water flow speeds and increases the rivers' natural capacity to absorb and redirect water during heavy rainfall events.

A healthy vegetated riparian area helps protect the banks from erosion and act as a buffer between land and water, filtering sediments and contaminants from runoff. They also serve to shade waterways, regulating temperatures, minimising algae growth, and provide for in-stream habitat.

With increases in hot days (>30°C) projected to occur in the catchment with climate change, a healthy riparian area can play a critical role in mitigating the potential effects of direct warming and heat contamination in freshwater environments that may occur during an extreme rainfall event in future.

Figure 12: Naturalisation of a previously channelised waterway, including daylighting piped tributaries, restoring riparian buffer vegetation and re-meandering waterway. Source: Boffa Miskell Ltd.

4.3 WETLAND RESTORATION & CONSTRUCTION

4.3.1 What is wetland restoration and construction?

Wetland restoration and construction works to intercept, accommodate, and process excess floodwaters flowing down the catchment during an extreme rainfall event. Through restoring or constructing natural wetland features, such as deep sedimentation ponds or shallow water vegetated areas, wetlands can detain large volumes of water and remove contaminants including suspended sediments and nitrates.

To successfully accommodate flood flows and significantly reduce contaminant load in runoff, as a rule constructed wetlands need to be between 1% and 5% of their contributing catchment size (Tanner *et al,* 2021). Wetlands smaller than this scale will be frequently overwhelmed by flood flows and provide insufficient time to enable contaminant reduction. This 1% to 5% wetland size refers to the actual 'wetted' area under normal flow conditions, this does not include the additional areas required for marginal planting and landscape modification.

Te Hakapupu/Pleasant River estuary wetland complex is a critical receiving environment within the catchment. However, classified as a Naturally Uncommon Ecosystem and vulnerable due to its historic reduction in size and ecological decline, the estuary wetland complex faces numerous pressures including invasion from invasive weed species, grazing of remaining wetland areas, and alteration of natural flow characteristics (Holdaway *et al.,* 2012).

Te Hakapupu/Pleasant River Estuary Wetland Complex currently covers approx. 84 hectares (~0.6% of the catchment) following significant historical drainage. Consequently, the current extent of the wetland area limits its natural ability to accommodate flood water during extreme rainfall events, causing flooding of homes, productive agricultural lands, and associated infrastructure located on reclaimed land. Additionally, the reduced wetland extent limits the assimilative capacity of the wetland, driving the high sediment mud content with the estuary.

4.3.2 How can wetland restoration and construction work as a NbS?

Surface-flow constructed wetlands are used nationally and internationally to collect, treat, and store stormwater runoff. By providing storage volume space to accommodate flood flows and vegetative resistance to slow flood flows, constructed and restored wetland areas can buffer the impacts of flood flows entering into important habitats and ecosystems, and prevent damage and disruption to surrounding land uses and infrastructure.

Plausible locations for wetland restoration and construction have been considered at the northern and western extent of the existing wetland complex. Located on reclaimed areas, these low-lying locations occupy the most flood prone areas within the lower catchment and are modelled to receive between 1.5m – 3m flood depths outside of the existing channel during an extreme rainfall event. Flood water tends to move at slower velocities within these areas as shown in Map 8.

Various locations across the mid and upper catchment also lend themselves to construction or restoration of both on-stream and off-stream wetlands and sediment detention ponds (as identified in the Catchment Action Plan, 2024). Whilst these add value to flood hazard mitigation across the catchment, restoration of the historically reclaimed estuary wetland complex is considered to provide the greatest biodiversity benefits and flood mitigation capacity.

Additionally, along with accommodating rainfall induced flood flows, the identified lower catchment wetland locations can act as a buffer for properties and assets potentially exposed to the future effects of coastal inundation from sea-level rise. Following late-century climate change projections (2090), these locations are projected to be exposed to inundation events from both extreme rainfall induced flooding and coastal storm surge.

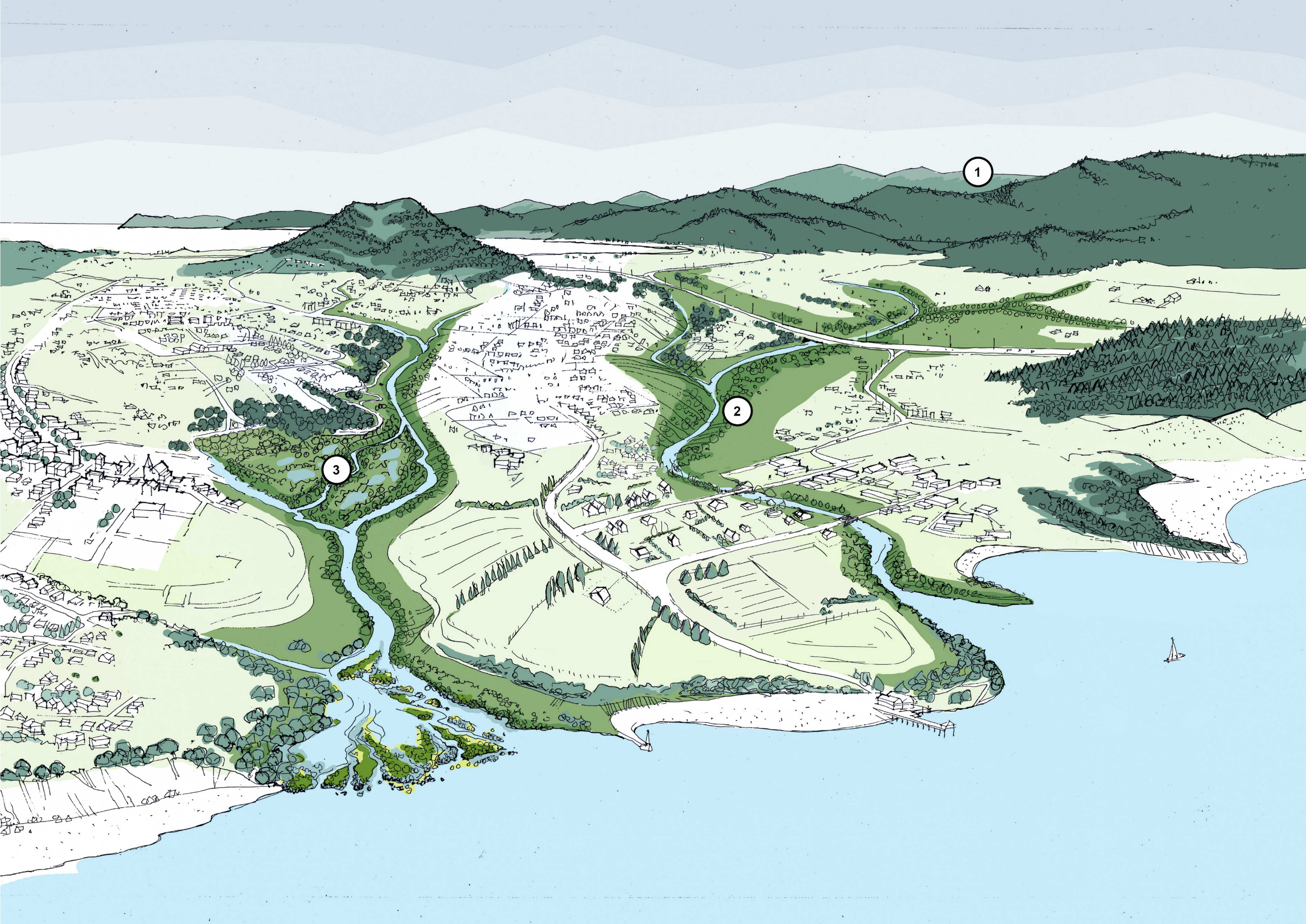
By locating surface flow wetlands within these lower catchment areas, this NbS seeks to work with the existing landscape to effectively accommodate flood waters, mitigating the impacts of a flood event.

Figure 13: Construction of a wetland in Thomsons catchment, Otago. Source: Manuherekia Catchment Group

4.4 OVERVIEW OF NATURE-BASED SOLUTIONS FOR TE HAKAPUPU/PLEASANT RIVER CATCHMENT

Table 3: Overview of the three NbS interventions that are tested in Te Hakapupu/Pleasant River catchment

	1. LANDCOVER MANAGEMENT	2. RIVER AND STREAM NATURALISATION	3. WETLAND RESTORATION AND CONSTRUCTION
FLOOD HAZARD MANAGEMENT TYPE	The landcover management NbS approach seeks to manage flood hazards through: a. Protection of lower catchment areas from flood flows and flood-related impacts of sediment mobilisation and debris flows through permanently retaining water yield moderation and stabilising steeper surfaces. b. Avoidance of 'windows of vulnerability' prompted by ongoing plantation forestry harvest and replanting cycles.	The river and stream naturalisation NbS approach seeks to manage flood hazards through: a. Mitigation of surface flooding through the slowing of peak flood flows by increasing water retention and allowing for runoff infiltration. b. Accommodation of additional flood waters during extreme rainfall events through possible increases in volumetric capacity of the river channel. c. Protection of vulnerable ecological and mahika kai values within the Te Hakapupu/Pleasant River catchment through the interception of runoff contaminants and mitigation of streambank erosion.	The wetland restoration and construction NbS seeks to manage flood hazards through: a. Managed retreat of built infrastructure and primary production land used away from flood prone areas b. Accommodation of excess slow moving flood waters during extreme rainfall events in increased water retention areas c. Protection of vulnerable ecological and mahika kai values within the Te Hakapupu/Pleasant River estuary wetland complex through the interception and treatment of suspended sediments and other contaminants
SCALE	Expansion of remnant indigenous forest areas overtime, planned in alignment with projected forestry harvest events to cover large upper sub-catchment areas.	River and stream naturalisation length to span the unvegetated areas of all three waterways of the mid-catchment Te Hakapupu/Pleasant River corridor, the mid-catchment Owhakaoho / Trotters Creek corridor, the mid-catchment Watkin Creek corridor.	New wetland restoration and construction area cumulatively spanning approx. 140 ha. Resulting in total catchment wetland area exceeding 1.75% total catchment size.
KEY CHARACTERISTICS	For existing pockets of remnant indigenous forest areas within the plantation forest estate, restoration and enhancement work would support connecting existing remanent bush and create new areas that can act as seed sources for large scale transition to native forest and other catchment restoration activities, such as riparian buffer area planting. For large scale transition of areas of plantation forestry to permanent indigenous forest, restoration activities would align with existing harvest timeframes. Locally sourced indigenous species would be used for planting, with preference to hardy, fast growing species that meet Emission Trading Scheme requirements (i.e., 5 m canopy).	For restoration of riparian buffer areas, given the relatively flat to undulating topography of the mid-catchment areas, at minimum a 3 m fenced setback is considered for the identified waterways in alignment with National Environmental Standards for Freshwater. Additionally, livestock will be fenced for exclusion from the riparian area and structures identified as High Risk and Very High Risk to fish passage removed or remediated. Through river and stream naturalisation, detached and degraded oxbow sections of waterways / off-stream wetland areas will be reconnected to provide additional water retention capacity and important fish spawning habitat. Riparian buffer areas will be planted with native sedge and rush species in lower wet stream banks, surrounded by hardy riparian species such as Carex and harakeke species on embankments and tall tree species along the corridor proximity.	Given the challenges with Te Hakapupu catchment faces with water quality, particularly sedimentation transported from upper catchment plantation forestry areas during heavy rainfall events, wetland inflow locations will be constructed with deeper sedimentation ponds (1-1.5m deep and 20% of immediate wetland area) at inlet to intercept and store suspended sediments. While also providing increased water retention and detention capabilities during flood events, these sedimentation ponds will support the prevention of sediment deposition that could adversely impact the vegetated areas of the main wetland and could be transported into the lower estuarine environment. Wetland areas will be planted with native wetland sedge and bulrush species in shallow zones, surrounded by hardy riparian species on embankments and riparian margins.
POSSIBLE CATCHMENT APPLICATIONS	Restoration and expansion of existing pockets of remnant indigenous forest, towards the gradual conversion to wide-scale permanent indigenous forest to occur across vulnerable upper sub-catchment areas, covering Te Hakapupu / Pleasant River, Owhakaoho / Trotters Creek, and Watkin Creek sub-catchments	Te Hakapupu/Pleasant River and Watkin Creek naturalisation proposed to occur along the majority of its mid-catchment length. The Owhakaoho / Trotters Creek naturalisation proposed to occur in the upper-mid-catchment section, west of Wairunga.	Wetland restoration and construction is proposed at the western and northern extent of the present-day estuary wetland complex, located at the confluence of Watkin Creek and the wetland, and following Te Hakapupu/Pleasant River northwest.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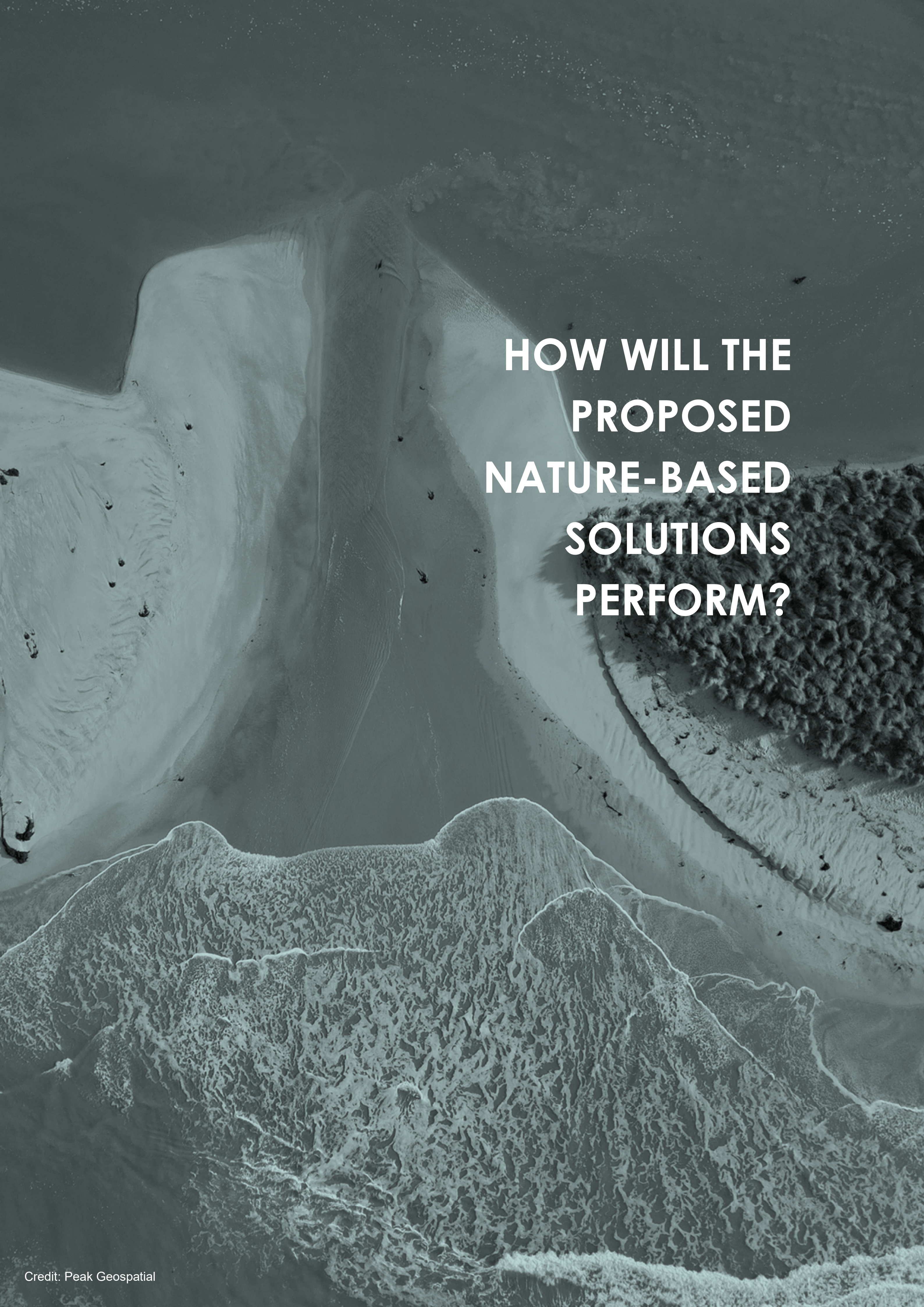
HOW WILL THE PROPOSED NATURE-BASED SOLUTIONS PERFORM?



Credit: Peak Geospatial

5. HOW WILL THE PROPOSED NBS PERFORM?

Using the functional criteria and relevant performance indicators from the NbS Technical Specification, the following evaluation criterion was applied to each NbS intervention to test the opportunities, challenges, and possible benefits of its use for flood hazard management in Te Hakapupu/Pleasant River catchment.

Table 4: Evaluation criteria for Te Hakapupu NbS Feasibility Study in relation to IUCN Global Standards for Nature-based Solutions relevant functional criterion and performance indicators

	TECHNICAL CRITERION	PERFORMANCE INDICATORS	EVALUATION CRITERION
HAZARD	Nature-based Solutions effectively address societal challenges	The societal challenges addressed are clearly understood and documented	How does the NbS contribute to flood hazard management in the catchment?
LANDSCAPE	Design of Nature-based Solutions is informed by scale	The design of the NbS is integrated with other complementary interventions and seeks synergies across sectors	How does the NbS contribute to landscape amenity value, character, and recreation opportunities?
BIODIVERSITY	Nature-based Solutions result in a net-gain to biodiversity and ecosystem integrity	The NbS actions directly respond to evidence-based assessment of the current state of the ecosystem and prevailing drivers of degradation and loss Opportunities to enhance ecosystem integrity and connectivity are identified and incorporated into the NbS strategy	What are the potential biodiversity benefits, challenges, and practicalities of the NbS in the catchment?
ECONOMIC	Nature-based Solutions are economically viable	Cost-effectiveness is considered to support the choice of NbS	What are the high-level costs of the establishment and maintenance of the NbS in the catchment?
COMMUNITY & CULTURE	Nature-based Solutions equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits	The potential costs and benefits of associated trade-offs of the NbS intervention are explicitly acknowledged and inform safeguards and any appropriate corrective actions	What are the potential impacts, benefits, and trade-offs the NbS may have in the catchment, alongside productive rural land uses and as part of Kāti Huirapa ki Puketeraki's takiwā?
CLIMATE	Nature-based Solutions are managed adaptively, based on evidence	A framework that enables adaptive management us applied throughout the intervention lifecycle	How does the NbS adapt to and/or help mitigate the effects of climate change in the catchment?
REGULATORY	NbS are sustainable and mainstreamed within an appropriate jurisdictional context	The NbS is informed by the facilitating policy and regulation frameworks to support its uptake and mainstreaming	Is the NbS consistent with consenting requirements and key legal or policy considerations? (e.g. land ownership, NPSFM, NESFW, NESPF, RPS, District Plan)

5.1 LANDCOVER MANAGEMENT

Landcover management will focus on the expansion of remnant indigenous forest pockets in upper sub-catchment areas, towards the gradual transition from clear fell plantation forestry to permanent indigenous forest in vulnerable locations. This NbS approach would seek to mitigate the effects of extreme rainfall induced flood through permanently restoring the natural hydrology in vulnerable upper sub-catchment areas.

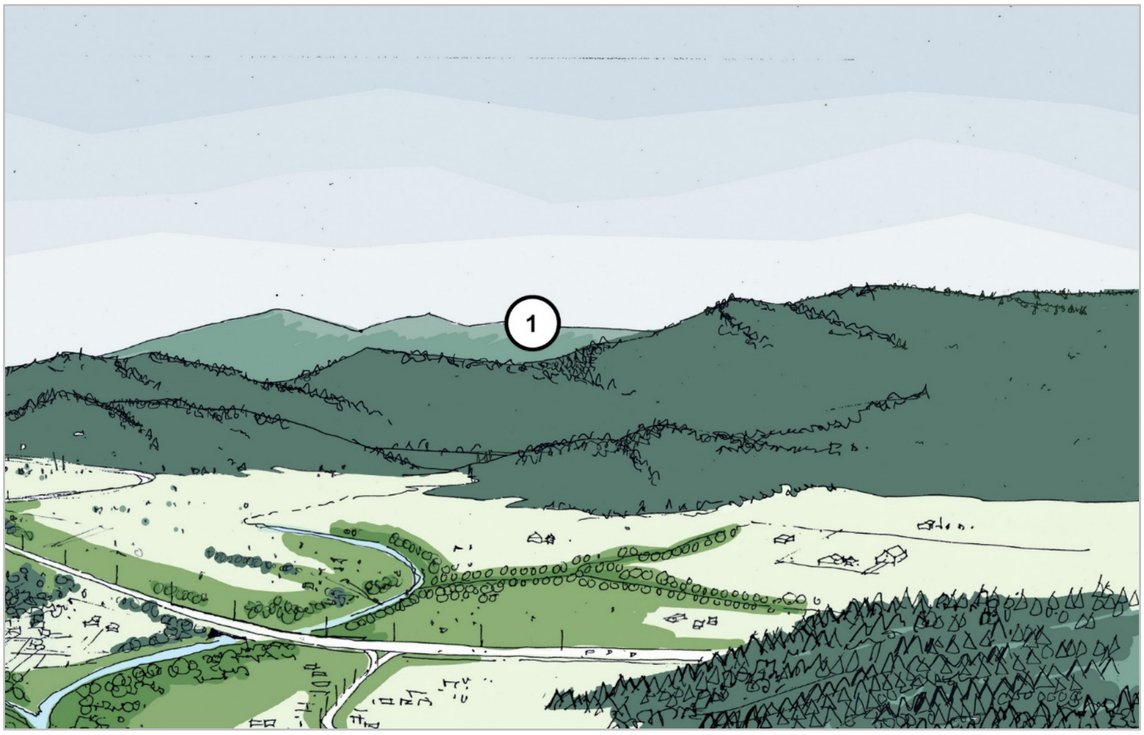


Figure 14: Possible application of landcover management in upper catchment areas in Otago catchments

5.1.1 How does landcover management contribute to flood hazard mitigation in the catchment?

In reference to the drivers of flooding and associated hazards within Te Hakapupu/Pleasant River catchment, this NbS would effectively increase environmental and infrastructure resilience in the catchment through the following means:

Protect: Protection of the relatively flat mid and lower catchment areas and land uses from exposure to the effects of flood flows and the flood-related impacts of sediment mobilisation and debris flows through permanently retaining water yield moderation and stabilisation of steeper surfaces.

Avoid: Avoidance of the windows of vulnerability, caused by ongoing plantation forestry harvest and replanting cycle in upper sub-catchment areas. These windows of vulnerability increase both the exposure and vulnerability of the relatively flat mid and lower catchment areas to increased flood flows and the flood-related impacts of sediment mobilisation and debris flows.

Overall, the Rapid Flood Hazard Model indicates that in a 100-year extreme rainfall event in a post-harvest scenario (i.e. during the period of plantation forestry harvest and replanting) there could be and increase in flow from upper catchment areas in the order of 25% or more, compared to the current plantation forestry coverage. This would likely exacerbate the impacts of flood events across the lower catchment.

If the current plantation forestry blocks in the upper catchment were transitioned back to a full native bush coverage, then a potential reduction in flow would be possible in the order of 6-7% during a 100-year extreme rainfall event, compared to the current plantation forestry coverage. Therefore, reducing the impacts of flooding across the lower catchment and avoiding increased flows during plantation forestry harvest and replanting periods.

5.1.2 How does landcover management contribute to landscape amenity value, character, and recreation opportunities?

The landcover management NbS intervention involves the restoration and expansion of existing pockets of remnant indigenous forest within the catchment, seeking a gradual, long-term transition of large areas in the upper sub-catchments from exotic plantation forestry to wide-scale permanent indigenous forest.

The restoration and enhancement work would support connecting existing remanent indigenous forested areas and create new areas that can act as important local seed sources.

Potential benefits

The long-term outcome of this NbS intervention would be a large-scale permanent indigenous forest across upper sub-catchment. Replacing the existing exotic plantation forestry with permanent indigenous forest will have a positive effect on the landscape, amenity and natural character values of the upper catchment areas and wider landscape.

By replacing the plantation forestry in vulnerable locations, the mobilisation of sediment and debris to waterways can be significantly mitigated, reducing flood-related risks in the catchment, effects on water quality and clarity, and effects on lower catchment freshwater and estuarine habitats. These changes would enhance and allow for the better protection of landscape and natural character values throughout the catchment, beyond the immediate location of the proposed change.

A gradual transition to permanent indigenous cover across upper sub-catchment would also have potential benefits for the perceptual and associative dimensions of landscape, and visual amenity, as well as the experiential aspects of natural character. The increase in native vegetation is likely to raise aesthetic values for example, in regard to levels of naturalness and visual coherence as it gradually leads to a more natural sequence of indigenous vegetation types in the area.

5.1.3 What are the potential biodiversity benefits, challenges, and practicalities of landcover management in the catchment?

Biodiversity benefits & challenges

Indigenous vegetation cover in the catchment is very limited (approximately 1%) and essentially all land cover is exotic in nature (pasture and plantation forestry). Gradual replacement of plantation forestry with permanent indigenous forests across large areas of the upper sub-catchments would massively increase local population sizes of indigenous flora and fauna species. Indigenous forest at large scales would, in time, be likely to be resilient and self-sustaining. Targeted plantings could be used to bolster desired threatened, at Risk or locally uncommon plant populations within the catchment.

Compared to tall exotic plantation forestry with high levels of rainfall interception and evapotranspiration, indigenous forest cover typically displays increased downstream water yield but reduced flow flashiness during rain events, an important 'win-win' in terms of buffering stream flows. They can therefore also act as 'water storage' during drier periods, mitigating currently occurring low flow periods in the catchment. Downstream runoff of sediment and 'flashy' stream flows in heavy rain events would be reduced in the long term if a large proportion of the catchment (particularly in steep and erodible areas) is permanently vegetated.

In regard to wider natural hazards in the catchment, extensive gorse or fast-growing successional indigenous forest types (e.g. kānuka scrub / forest) are flammable and vulnerable to fire. This also applies to existing pine plantations. Long term, mixed broadleaf native forests are generally resistant to fire.

Practicalities of implementation

The cost, nursery infrastructure, personnel, and planting maintenance requirements for large scale indigenous afforestation likely make an approach reliant on wholesale / widespread indigenous plantings infeasible. Therefore, any realistic approach would be reliant on facilitating native forests to regenerate themselves with minimal interference. This would likely still require targeted pest control (focused on the most concerning / habitat-altering plant and animal pests). Because of the limited existing seed source for indigenous forest species in the catchment, this approach would also be reliant on the rate and extent of natural spread from adjoining indigenous habitats, such as on Mt Watkins / Hikaroroa, and / or targeted indigenous plantings of 'nodes' to accelerate natural regeneration processes.

Noting the potential fire risk, an interim vegetation cover of gorse or other pioneer exotic species may establish in the short term, but in the long term (~30 years), with sufficient seed source, succession to native vegetation cover would be expected. Ongoing and effective suppression of browsing mammals will increase regeneration rates, as will interventions that increase populations of species such as kereru that are capable of transporting fruits of large-seeded tree species.

A more feasible approach than planting following forestry harvest may be to underplant indigenous species beneath an in-situ pine canopy. However, the major limitations of indigenous seed source and pests noted above would also apply. Additionally, harvest practices of the pine canopy would need to avoid damage and destruction of emerging indigenous species. If 'nodes' of plantings are used, this would likely still require many 10s-100s of thousands of plants, and as above, this would require several years lead-in time for a specialist nursery to propagate. While low stature plantings may mature within a short time frame (<5 years), many forest tree / shrub species are slow-growing and will not mature for many decades (or centuries).

5.1.4 What are the high-level costs of the establishment and maintenance of landcover management in the catchment?

Establishment & Maintenance costs

Landcover management approaches of transitioning exotic plantation forestry into large scale permanent indigenous forest areas incur a number of costs associated with the establishment and upkeep of indigenous species. For large-scale indigenous afforestation being considered in this NbS intervention, afforestation estimates vary depending on access and existing environment, although broadly:

- The Climate Change Commission estimates that the establishment costs for large scale indigenous afforestation are estimated to be around $6,600 per hectare and can be as high as $24,000 to $50,000 per hectare (CCC, 2021).

- Motu Economic and Public Policy Research estimates that large scale indigenous afforestation establishment costs range from $24,000 to $66,000 per hectare (Pohatu *et al.* 2020)

These estimated costs do not consider the maintenance costs associated with indigenous plantings. The cost of fencing, planting, and continuous weed and pest management could range from $12,000 to $15,000 per hectare (Pohatu et al., 2019). By aligning with the wider Te Toitū Te Hakapupu restoration project for indigenous afforestation, this NbS may be able to recognise a couple of cost reduction opportunities for landowners, including plant purchasing and planting.

PLANT PURCHASING: Sourcing of suitable plant species for indigenous afforestation may be propagated from remnant pockets of indigenous forest through establishment of a community nursery. Additionally, with suitable plant species already present in remnant indigenous forest pockets in the upper catchment, controlling weed species and invasive browsing pests may be sufficient to enable those remanent pockets to expand across large area naturally over time. Although, it should be noted that natural regeneration in coastal Otago is slower compared to other more temperate North Island regions. Alternatively, crowd sourcing mechanisms such as ‘Trees that Count’ could be applied to provide funding for plant purchase or aligning with national government afforestation grants.

PLANTING: Planting efforts can be supported by using community groups, public planting days, or facilitating corporate volunteer planting days.

Land use change costs

Forestry and logging are an important industry within the Otago Region and Waitaki District economies, adding approximately $81 million of value to the regional economy and $13 million of value to the district economy (Yang *et al.* 2023). Although permanent indigenous forestry does not often match the same financial returns as plantation forestry, indigenous afforestation provides an opportunity for reducing sediment and nutrient losses, enhancing indigenous biodiversity, offsetting greenhouse gas emissions, and contribution to wider ecosystem services such as fibre, animal shelter, habitat for beneficial species and aesthetic.

Under present-day (2025) market settings, the transition of land use from exotic plantation forestry to permanent indigenous forestry would likely incur significant economic costs for landowners. With plantation forestry blocks in the upper catchment participants in the New Zealand Emissions Trading Scheme (NZ ETS), under current NZ ETS settings, transitioning exotic plantation forest cover to be replaced by smaller, slower growing indigenous species would reduce forest carbon stocks in the near to midterm, incurring significant carbon credit surrender liabilities for landowners. As indigenous forests and exotic forests recognised within the NZ ETS sequester and store carbon at different rates, when mature exotic forests are gradually replaced with new indigenous forest species, the overall carbon stock will progressively reduce.

Indigenous forests are expected to sequester high levels of carbon in the long-term than compared to exotic forest species. However, after 100-years, the amount of carbon stored in an indigenous forest would still likely be below the initial 40-year peak of an exotic forest. This deficit in carbon stocks between exotic and indigenous forest species creates a large financial liability for participants.

Without change in NZ ETS settings to encourage greater levels of indigenous afforestation, this NbS intervention would present a financial risk to forestry participants within the catchment and disincentives the long-term transition at a large scale (MPI, 2023).

5.1.5 What are the potential impacts, benefits, and trade-offs landcover management may have in the catchment, alongside productive rural land uses and as part of Kāti Huirapa ki Puketeraki's takiwā?

The NbS intervention of landcover management align with the identified values and strategies of the draft Toitū Te Hakapupu CAP (Ahikā, 2023). The relevant values and strategies are detailed below.

Value 1: Waterways

Value 1 of the draft Toitū Te Hakapupu CAP recognises that waterways in the catchment and the estuary wetland complex provide important habitat and eco-system services, however, these values have been degraded over time, particularly due to the effects of plantation forestry operations in the upper catchment. The NbS intervention of landcover management would contribute benefits towards the enhancement of Value 1, specifically aligning with the following CAP strategies:

- S1A. Levels of contaminants and sediment entering waterways & estuary wetland complex will be reduced, in accordance with target attribute states as set out in the LWRP
- S1F. Instream flows and hydrological functions are maintained or improved in the catchment, including restoring wetlands, re-naturalising waterways and managing invasive plant species, where this does not increase flood risk

With the gradual transition of upper sub-catchment landcover from clear-fell plantation forestry to permanent indigenous forest, this NbS would significantly reduce the window of vulnerability to increased sediment and debris inputs catchment waterways are exposed to during harvest and replanting periods.

The high-risk period during the ‘window of vulnerability’ exists for approximately 8-years from the time of harvest until the replanted crop establishes a full canopy and sufficient root structure. During this window, the loss of canopy cover and root structures in the steeper upper catchment areas would see an increase in overall water yield into the lower catchment during rainfall events, likely transporting fine sediments and other woody debris.

During extreme rainfall events, it is often the debris flows that cause the greatest damage to lower catchment waterways.

With the effects of sediment inflows into the main waterways already creating issues with water quality in the lower catchment and estuary wetland complex, restoring the upper catchment watershed to permanently avoid the increased risks posed by forest harvest would likely contribute the greatest benefits to achieving CAP water quality related strategies.

Value 2: Biodiversity

Value 2 of the draft Toitū Te Hakapupu CAP recognises that biodiversity within the catchment provides important habitat, ecosystem services, and landscape amenity. However, with the widescale modification of the indigenous environment over time towards a predominant mix of exotic pastoral and forest land cover, these values have been diminished. The NbS intervention of landcover management would contribute benefits towards the enhancement of Value 2, specifically aligning with the following CAP strategies:

- S2A. Existing remnants of indigenous vegetation and wetlands will be identified, protected, and enhanced
- S2B. Increase indigenous plantings in the catchment to support the creation of biodiversity corridors, including within the forestry estate

Within the existing plantation forestry areas across the upper catchment, a number of small remanent indigenous forest pockets provide isolated habitat for biodiversity. Through initially seeking to protect and enhance these remanent indigenous forests and support their expansion across larger areas of the upper catchment, connectivity can be enhanced.

Value 3: Cultural significance

Value 3 of the Toitū Te Hakapupu CAP recognises that the Hakapupu catchment is part of Kati Huirapa ki Puketeraki’s takiwā and is culturally significant, however as mana whenua have lost access to large parts of the catchment and natural environment values have degraded, these values have become increasingly limited. The NbS intervention of landcover management would contribute benefits towards the enhancement of Value 3, specifically aligning with the CAP strategies:

- S3A. Water quality and habitat will be protected and enhanced with a focus on mahika kai and taonga species so that abundance is sufficient to support cultural practices.
- S3B. Access to key sites for cultural practices will be investigated, and where possible, re-established.
- S3C. Existing trails and access points will be enhanced.

For mana whenua, enhancing safe access to upper catchment areas where mahika kai values are supported helps sustain connections to wāhi tupuna and transfer of mātauraka Māori. Through the landcover management NbS intervention, mana whenua and community access to upper catchment areas could be safely enhanced without public interference in clear fell forestry operations. Access to key cultural sites could be supported through restoration activities, with opportunities to share mātauraka Māori for the sustainable use and protection of biodiversity values and taonga species.

5.1.6 How does landcover management adapt to and/or help mitigate the effects of climate change in the catchment?

Climate change adaptation

Beyond permanent indigenous forests being more resilient to the effects of extreme rainfall events and land instability, mature indigenous forest cover can support reducing catchment vulnerability to fire-related risks. The climate change effects on fire-related risks in New Zealand is an emerging research area. As such, the direct change a warmer and drier summer climate may have on fire risk within the catchment has not been specified within Otago Region Climate Change Projections (Macara *et al.* 2019). However, with more frequent extreme hot days and dry days (≤1mm) projected to occur across the Otago region, fire-risk profile of exotic forested areas may be subject to change.

Climate change mitigation

Undertaking a gradual transition from exotic plantation forestry to permanent indigenous forest presents both benefits and disbenefits for climate change mitigation – causing disbenefits in the near to mid-term, but benefits in the long-term. As detailed in the economic evaluation of this NbS, transitioning exotic forest species to permanent indigenous forest species creates change in the net-carbon stocks of a forested area, where the benefits will likely not be realised until future generations. Exotic forest species typically grow much faster than New Zealand indigenous species, sequestering and storing carbon within their biomass at a much higher rate per year. However, with slow continuous growth indigenous forests are expected to sequester comparatively high levels of carbon in the long-term.

In the scope of immediate climate change mitigation requirements, New Zealand, along with the rest of the world must rapidly reduce its net-carbon emissions in the coming years in effort to hold global warming well-below 2°C. The window of opportunity to achieve this target and avoid the more severe effects of climate change is closing fast within this decade (IPCC, 2021). Accordingly, reducing net-carbon stocks stored within Te Hakapupu forested would likely provide a disbenefit to net-emissions reduction efforts required to achieve near and mid-term emission budgets.

Alternatively, however, transitioning the catchments forested areas to permanent indigenous may contribute positively to national climate change mitigation efforts, as New Zealand must reach net-carbon zero and remain at net-carbon zero. Well-maintained permanent indigenous forests provide for longer term carbon sequestration beyond the end of this century and ensure greater permanence of carbon stocks. As climate change intensifies, the risks to exotic forestry plantations, such as flooding and fire, also increase. In contrast, permanent forest species with a well-established understory tend to be less vulnerable to these hazards.

5.1.7 Is landcover management consistent with consenting requirements and key legal or policy considerations?

Land ownership characteristics

The landcover management NbS would likely occur over the largest area of the three NbS, across large sections of the upper sub-catchments. There are 48 parcels of land in the forested upper catchment, and a total of 19 landowners, predominantly private entities.

There is a number of forestry companies who hold significant areas of land within this area, with Calder Stewarts, PF Olsen, Wenita, and Ngāi Tahu Forestry being the largest landowners.

Regulatory implications

At a very high-level, the NbS intervention of landcover management essentially seeks to facilitate the gradual conversion of exposed clear-fell plantation forestry areas to permanent indigenous forests. This NbS might involve the following activities (assuming that clearance of existing plantation forestry is undertaken in accordance with relevant rules and standards):

- Planting of indigenous vegetation, which may include within riparian areas
- Ancillary earthworks
- Fencing to exclude stock and browsing pests from restored areas

A summary of the potential consenting requirements associated with these activities under the relevant regulatory instruments is set out in Appendix 6. Note that it is assumed that the works will not occur in proximity to any inland natural wetlands as defined in the NPS-FM, but that a detailed site survey should be undertaken to verify this. If natural inland wetlands are affected, then there could be consent requirements under the NES-F.

Similarly, this NbS is not anticipated to trigger any consent requirements under the Otago Regional Plan: Water as it is unlikely to involve the types of activities managed under that plan (e.g. damming, diversion, discharge of water).

Policy considerations

General Policy Direction

It is expected that any improvement to water quality and freshwater habitat that arises as a result of the NbS would be broadly consistent with the general policy direction in the NPS-FM and the Otago Regional Plan: Water.

National Policy Statement – Indigenous Biodiversity

The NPS-IB has an overarching objective of maintaining indigenous biodiversity across Aotearoa New Zealand so that there is at least no net loss in indigenous biodiversity after the commencement date of the NPS-IB. Related policies seek to promote and provide for the restoration of indigenous biodiversity, [9] and to promote increased vegetation cover in both urban and non-urban environments.[10]

[9] NPS-IB Policy 13
[10] NPS-IB Policy 14

Dunedin District Plan

Objectives and policies in the Dunedin District Plan seek to maintain or enhance biodiversity values, including by encouraging conservation activity in all zones through the district. [11] Objective 16.2.3(f) seeks to maintain or enhance the rural character values and amenity of the rural zone, including by including extensive areas of indigenous vegetation and habitats for indigenous fauna. [12]

Waitaki District Plan

The Waitaki District Plan identifies ongoing modification and degradation of nature conservation values in the District as one of the key issues within the Rural parts of the District.[13] Related objectives seek to maintain biodiversity, nature conservation values and ecosystem functioning; as well as the quality of water, wetlands, lakes, rivers and their margins. [14]

Overall, landcover management would be generally consistent with the policy direction of the NPS-FM; NPS-IB; Otago Regional Plan: Water; the Waitaki District Plan; and the Dunedin District Plan.

Figure 15: Landcover post forestry harvest, Southland. Source: Videocopter.

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[11] Dunedin District Plan Objective 10.2.1 and Policy 10.2.1.5
[12] Dunedin District Plan Objective 16.2.3(f)
[13] Waitaki District Plan Issue 8
[14] Waitaki District Plan Objectives 16.9.2(1) and (2)

5.1.8 Summary of landcover management as a nature-based solution

Opportunities

- This NbS intervention would permanently restore the natural hydrology of vulnerable areas in upper sub-catchment locations, avoiding the exacerbation of flood hazards during forestry harvest and replanting periods.
- Permanent indigenous afforestation typically increased downstream water yield but reduced flood flows, addressing flood hazards but not exacerbating water pressures during dry spells.
- The NbS is broadly consistent with national and local policy and planning direction.
- The NbS would significantly increase indigenous plant populations in the catchment, enhancing cultural and community amenity values.

Challenges

- Considerable economic costs are associated with the establishment and upkeep of indigenous forests at large scale and loss of plantation forestry revenue.
- Likely reduce the overall forest carbon stock for decades, incurring significant NZ ETS carbon credit surrender liabilities for landowners and impacting climate change mitigation targets.
- Would require action of up to 19 landowners to be implemented in vulnerable areas across upper sub-catchment locations.

5.2 RIVER NATURALISATION

The NbS intervention of river and stream naturalisation would target the predominantly unvegetated riparian areas of the main Te Hakapupu / Pleasant River, Watkin Creek, and Owhakaoho / Trotters Creek waterways. This NbS would seek to manage flooding and associated hazards along the middle and lower waterway corridors, primarily through slowing flood flow velocities and intercepting runoff.

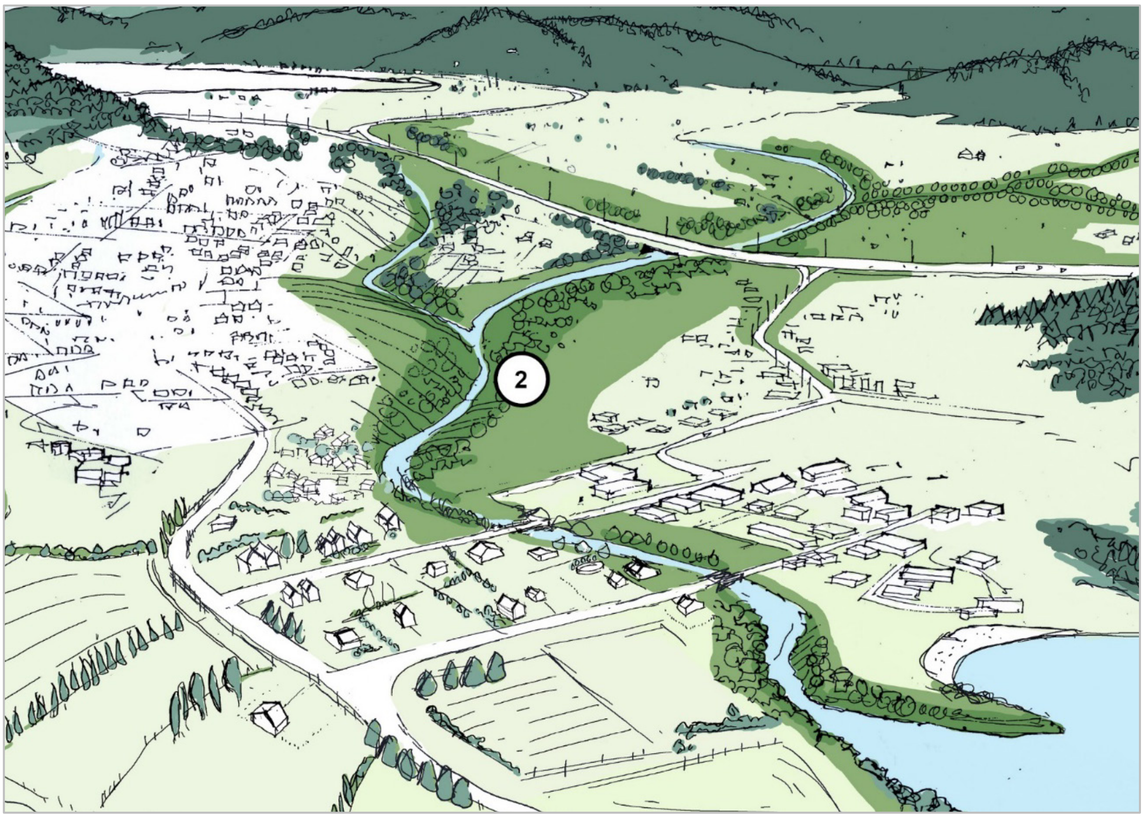

Figure 16: Possible application of river naturalisation in a typical Otago river catchment

5.2.1 How does river naturalisation contribute to flood hazard mitigation in the catchment?

In reference to the drivers of flooding and associated hazards within the Hakapupu catchment, this NbS would effectively increase resilience to the experienced impacts of flood events through the following means:

Avoid: Mitigation of severe surface flooding of areas and land uses vulnerable to the effects of flood hazards adjacent to waterway corridors, by enhancing riparian areas to slow runoff entering waterway, increase bank permeability, and slowing in stream peak flood flow velocities flowing down the catchment.

Avoid: Avoidance of fast flowing flood waters and unrestricted surface runoff from surrounding productive lands entering waterways, causing high levels of streambank erosion and transporting contaminants, by enhancing riparian areas to stabilise streambanks and intercept runoff contaminants.

While there is evidence of channel modification in the catchment through diverting and straightening through some properties, the main channels are is largely still that of a braided river system – so there would only be localised opportunities to implement changes. Compounding this, the flood extent shown in Map 7 is significant. Naturalisation of these localised areas (through reinstating a more sinuous channel form and increasing storage) would be unlikely to be of a scale that would make a significant change in flood extent.

Restoration of riparian vegetation would likely achieve benefits in terms of erosion management and protection of channel banks, but also may result in increased channel roughness and reduced channel capacity.

5.2.2 How does river naturalisation contribute to landscape amenity value, character, and recreation opportunities?

This NbS intervention involves undertaking river and stream naturalisation along modified waterways at Te Hakapupu/Pleasant River, Owhakaoho / Trotters Creek, and Watkin Creek. This will be achieved through the exclusion of stock and development activities within riparian buffer areas and the restoration of riparian vegetation with native shrubs and tall native tree species along the waterway corridor.

By naturalising these waterways within the catchment there is an opportunity to restore the natural flow characteristics, slow peak flow velocities, and increase their capacity.

Existing character and values

The main tributaries of Te Hakapupu/Pleasant River, Watkin Creek, and parts of Owhakaoho/ Trotters Creek in the mid-catchment are currently modified through agricultural and infrastructure development. While some work has been done through the Toitū Te Hakapupu project to enhance riparian planting, overall, they have relatively bare, unvegetated riparian margins and entrenched channels with small adjoining tributaries and wet areas being piped or cut off.

Potential benefits

This NbS seeks to restore the mid-catchment sections of the three main river corridors to vegetated riparian margins which will enhance the landscape, amenity and natural character values of the river corridors and the wider catchment.

Creating vegetated riparian buffers will enhance physical landscape values, abiotic aspects, and biotic aspects of natural character which have been degraded. This will be achieved through protecting the riverbanks from further erosion, restoring natural flows, improving water quality and clarity by filtering sediments and contaminants, increasing biodiversity, and providing shade over the waterways. Shade from the plants will assist rivers' life-supporting capacity for aquatic ecosystems. Reducing the sediment and nutrients that get into the waterways will also assist with better protecting the range of landscape and natural character values of Te Hakapupu/Pleasant River Estuary Wetland Complex at the lowest part of the catchment. Restoring and naturalising these corridors will also enhance values relating to perceptual and associative dimensions of the wider catchment's landscape and visual amenity values, particularly as a result of planting the bare riverbanks.

5.2.3 What are the potential biodiversity benefits, adverse effects, and practicalities of river naturalisation in the catchment?

Biodiversity benefits & challenges

At present, the riparian vegetation cover along the main waterways in the catchment is largely limited (i.e. bare or grassed banks) and / or exotic in nature (e.g. plantation forestry and willow). River naturalisation including riparian plantings would create greater ranges and larger population sizes of indigenous flora and fauna species, and the re-creation of 'natural' indigenous sequences of riparian vegetation.

Targeted plantings could be used to bolster desired Threatened, At Risk, and locally uncommon plant populations within the catchment. In turn, by creating vegetated corridors, habitats suitable for use by terrestrial fauna (i.e. birds, lizards, and invertebrates), or riparian nesting habitat for waterfowl and wetland bird species, may develop in time. Increased riparian cover utilising indigenous plant species may improve in-stream habitat conditions by, for example, intercepting sediments and runoff, by providing riparian shade, and by reducing pulses of leaf litter from exotic riparian species (e.g. willows).

Works to re-align or 'make room for the river' will require robust erosion and sediment control measures in place. Salvage and translocation of freshwater fauna may be required if works include temporary channel dewatering and realignment. Works to re-align or 'make room for the river' will also need to ensure that hydrological conditions within the 'typical' or 'low flow' channel remain suitable for freshwater fauna. Excessively widened waterways risk reducing water velocity and depth, increasing water temperature and / or enabling macrophyte growth, sediment build up at the exclusion of suitable conditions for freshwater fauna.

Conversely, narrow waterway corridors of riparian plantings inherently suffer from 'edge effects' that reduce the long-term resilience and functioning of plant communities. In turn, this creates opportunities for ongoing weed invasion. This weed invasion risk may be mitigated by greatly increasing the width of planted areas.

Practicalities of implementation

Earthworks to 'create room for the river' and conduct any re-align waterways will trigger potentially complex consenting and permitting requirements. Ecological input into plantings and design (including constructed bank, streambed substrates, depths, and structures such as bridges if any), and effects assessment for consenting and permitting processes would be required.

Establishing riparian plantings of at least 3 m width along the unvegetated areas of Te Hakapupu / Pleasant River, Owhakaoho / Trotters Creek and Watkin Creek corridors equates to approximately 3 ha of plantings. Whilst this potentially means 30,000 plants are required, this NbS solution is considerably more straightforward and of smaller scale than the wetland construction and restoration or landcover management NbS approaches.

Plants for this NbS would require several years lead-in time for a specialist nursery to propagate. While low stature plantings may mature within a short time frame (<5 years), many riparian tree / shrub species are slow-growing and will not mature for many decades (or centuries).

5.2.4 What are the high-level costs of the establishment and maintenance of river naturalisation in the catchment?

Establishment and maintenance costs

Establishment and maintenance costs of river and stream naturalisation within the catchment are primarily associated with the costs of fencing and restoring riparian setback areas as detailed in Table 5.

Similar to wetland restoration and construction activities, aligning with the wider Toitū Te Hakapupu restoration project that includes stream naturalisation, this NbS may be able to recognise a couple of cost reduction opportunities for landowners, including:

PLANT PURCHASING: Sourcing of suitable plant species for riparian areas may be selectively sourced or propagated from neighbouring well-established riparian areas within the catchment. Additionally, suitable plant species may already present in the proposed locations in which case, simply removing grazing pressure and controlling weed species may be sufficient to enable those remanent riparian plants to expand along the waterway corridor.

Alternatively, crowd sourcing mechanisms such as 'Trees that Count' could be applied to provide funding for plant purchase.

PLANTING: Planting efforts can be supported by using community groups, public planting days, or facilitating corporate volunteer planting days

Table 5: Indicative costs per hectare of activities associated with river and stream naturalisation

	INDICATIVE COST	$/HA (EXCL. GST)	NOTES
SITE PREPARATION	$0.5 per plant	$2,222	Spot spraying cost per plant. Alternatives are to spray whole area or use mechanical clearance.
FENCING	$20 - $30 per l/m	$20,800 – $31,200	Retirement fencing with electric 4-wire assuming 20 m wide x 500 m long planting area, fencing both sides 1040 m)
PLANT PURCHASE	$1.80 - $5 per plant	$8000 - $22,220	Assuming a mix of shrubs and trees in revegetation/forestry grades
PLANTING	$2 - $3 per plant	$8,880 - $13,330	Including $0.2 cost for fertilizer tab per plant. $0.35 for bamboo stake to allow for location.
REPLACEMENT PLANTING	$1.80 - $5 per plant	$2,500 - $5,000	5% mortality assumed; includes plant purchase and planting
PROJECT MANAGEMENT	$1 per m^2 of riparian area	$10,000	Generally, works managed by landowner or, Landcare group, NGO or Council and don't typically see a PM cost.
MAINTENANCE	Lump sum	$2,000 - $4,000	Allow for three visits over 2 years of maintenance
TOTAL COST PER HA		$54,000 - $88,000 per hectare	

Land use change costs

River and stream naturalisation along the waterways of the Hakapupu catchment would require the exclusion of stock grazing and setback from waterway margins. Should exclusions be greater than current regulation to achieve greater flood mitigation and biodiversity benefits, this would reduce the productive area on farms and require alternative the provision of water supplies for livestock.

While national cost-benefit analysis (economic cost vs environmental benefits) of riparian restoration for a variety of low, medium, and high-cost restoration scenarios and buffer widths found benefits typically outweigh the costs by between 2:1 and 20:1, this does not consider the impacts that direct personal costs may have on individual landowners (Eppink *et al.* 2016).

As common with NbS benefit realisation, the benefits of implementing wide-scale riparian restoration activities may provide significant benefits for flood mitigation and water quality. However, these broader benefits may not provide direct financial benefits to individual landowners. In comparison, without national or regional funding to support riparian restoration, the direct costs of fencing and restoring riparian margins, developing alternative water sources, as well as the opportunity loss through loss of productive land area could be difficult and expensive for farmers (Daigneault *et al.* 2017; B+LNZ & Federated Farmers, 2020).

Land use change benefits

DairyNZ commissioned research in 2021 to investigate the cost-benefits of ‘Productive Riparian Buffers’. The aim of this research sought to develop edge-of-field agricultural methods that improve water quality and ecological conditions, while also providing production benefits for farmers (Matthews & Matheson, 2021). Although a number of the productive buffers analysed do not meet NbS definition or criteria, options including planting tōtara along waterways to produce commercial by-products of foliage for oils and pole, and planting mānuka for foliage for essential oils may be viable in Otago. However, these financial benefits of these productive riparian buffer options are limited due to the high harvest labour requirements and limited market opportunities at present.

While vegetated riparian margins are not typically recognised within the NZ ETS, restoration and establishment of riparian margins at the appropriate scale could yield afforestation carbon credits.[15] Alternatively, riparian margins of smaller sizes (not complying with NZ ETS requirements) may be recognised at present through Voluntary Carbon Market (VCM) verification bodies should they meet requirements for additionality, transparency, and permanence.

While the amount of carbon sequestered is dependent on the biomass present within a riparian area (plant size and area) and its growth rate over time, the median sequestration values for riparian areas in New Zealand are estimated at 3.4 tonnes CO_2 per hectare per year.

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[15] Current NZ ETS settings require post-1989 forests to be at least 1 ha in size, 30m wide, and consist of a 5m tall canopy.

5.2.5 What are the potential impacts, benefits, and trade-offs river naturalisation may have in the catchment, alongside productive rural land uses and as part of Kāti Huirapa ki Puketeraki's takiwā?

The NbS intervention of river and stream naturalisation align with the identified values and strategies of the draft Toitū Te Hakapupu CAPP (Ahikā, 2023). The relevant values and strategies are detailed below.

Value 1: Waterways

Value 1 of the draft Toitū Te Hakapupu CAP recognises that waterways in the catchment provide important habitat and eco-system services, however, these values have been degraded over time, particularly due to the modification and management practices around streambanks. The NbS intervention of river and stream naturalisation would contribute benefits towards the enhancement of Value 1, specifically aligning with the following draft CAP strategies:

- S1A. Levels of contaminants and sediment entering waterways and estuary wetland complex will be reduced, in accordance with target attributes states set out in the LWRP
- S1B. Riparian margins will be protected and enhanced, with stock and plantation forestry excluded
- S1C. Fish spawning areas will be protected and enhanced, and fish passage will be enhanced.
- S1F. Instream flows and hydrological functions are maintained or improved in the catchment, including restoring wetlands, re-naturalising waterways and managing invasive plant species, where this does not increase flood risk.

The naturalisation of the main waterways identified in the catchment would predominantly be achieved through the exclusion of livestock and enhancement or restoration of riparian margin vegetation. Conducted at an appropriate scale across the waterway corridors, this can support reducing the contaminants and sediment entering waterways and being transported into the estuary wetland complex. Suitably sized and maintained riparian areas support contamination removal from surface runoff from surrounding productive land uses through a combination of physical and biological processes.

By providing for enhanced riparian vegetation cover, shallow surface runoff flows experienced during extreme rainfall events can be slowed, allow particles (sediment, livestock waste, plant debris) to settle on bank areas, and slow the velocity of runoff.

Additionally, by increasing surface permeability, enhanced riparian areas can facilitate more surface runoff to infiltrate into the riparian soil, increasing the contact between soil and contaminants such as dissolved nitrogen and fine sediments (McKergow *et al.* 2022). The estimated performance of a well restored and vegetated riparian area for filtering sediment, nitrogen, and phosphorus from surface run off will vary dependant on topography and riparian setback width, however performance will generally increase with setback width.

Restoration and naturalisation of stream corridors in the catchment can also play an important role in reducing erosion and enhancing freshwater habitats, noting that stream bank erosion accounts for as much as 98% of deposited sediment at catchment outlets into the estuary wetland complex. Through enhancing the root systems across a stream bank, riparian plants help to stabilise stream banks and buffer them from the effects of fast flows during extreme rainfall events, reducing sediment input from streambank erosion.

Value 2: Biodiversity

Value 2 of the draft Toitū Te Hakapupu CAP recognises that biodiversity within the catchment provides important habitat, ecosystem services, and landscape amenity. However, like the pressures experienced by waterways, these values have been degraded over time, particularly due to the modification and management practices around streambanks. The NbS intervention of river and stream naturalisation would contribute benefits towards the enhancement of Value 2, specifically aligning with the following draft CAP strategy:

- S2B. Increase indigenous plantings in the catchment to support the creation of biodiversity corridors, including within the forestry estate.

River and stream naturalisation of the presently unvegetated riparian areas of the main waterways within the catchment can support the enhancement of habitat and ecological functions of freshwater ecosystems. Key benefits that may enhance the biodiversity values found within catchment freshwater environments include:

- Reducing nutrients and sediments entering the waterway
- Providing or capturing organic material which can function as an important source of energy and serve as habitat for instream organisms
- Providing shading to moderate extreme temperatures in waterways.

Value 3: Cultural significance

Value 3 of the draft Toitū Te Hakapupu CAP recognises that the Hakapupu catchment is part of Kati Huirapa ki Puketeraki's takiwā and is culturally significant, however these values are diminishing as habitat available for mahika kai and taonga species is degraded. The NbS intervention of river and stream naturalisation would contribute benefits towards the enhancement of Value 3, specifically aligning with the CAP strategy:

- S3A. Water quality and habitat will be protected and enhanced with a focus on mahika kai and taonga species so that abundance is sufficient to support cultural practices.

River and stream naturalisation within Te Hakapupu catchment would provide beneficial outcomes for protecting and enhancing mahika kai abundance found within the catchment waterways by seeking to reduce the degrading pressures on these values from surrounding productive land uses. Riparian areas can be restored to contain a range of culturally important plant species, including those used for weaving or traditional medicines. Noting that important mahika kai species including Tuna, Banded kōkopu, and Īnaka are all ranked highly vulnerable to the effects of climate change, enhancing riparian areas to provide resilient habitat for these species will help protect these values for future generations (Egan *et al.* 2020).

5.2.6 How does river naturalisation adapt to and/or help mitigate the effects of climate change in the catchment?

Climate change adaptation

River and stream naturalisation of the currently unvegetated waterways of Te Hakapupu / Pleasant River, Watkin Creek, and parts of Owhakaoho / Trotters Creek, as identified in the NbS intervention, would provide beneficial outcomes to increasing the resilience of these freshwater environments to the effects of climate change.

As global warming drives the increase in mean annual temperatures across the Otago region in the coming decades, under a 'hot house' (RCP 8.5) climate change scenario, the catchment is projected to experience an increase of up to 1°C by 2040 and 2-2.5°C by 2090 (relative to a preset-day 1986-2005 average). Accordingly, as mean annual temperature increases, so too does the likelihood of extreme hot days (≥30°C). An additional 5 extreme hot days are projected annually for the catchment under a 'hot house' scenario by 2090.

Restoring riparian vegetation along the corridors of the main waterways across the catchment can reduce the effects of heat stress in freshwater environments, both through the shading of exposed areas during extreme hot days and by preventing heat contamination from runoff across hot surfaces entering waterways. Heat stress and surface water runoff across hot surfaces into surrounding waterbodies (e.g. a rainfall event after an extremely hot day) presents climate-related health risks to freshwater fish species. Sudden changes in water temperatures can alter the physical habitat conditions in freshwater environments and cause a range of physical and behaviour responses in freshwater species, through to death in severe circumstances.

Additionally, through re-establishing pre-existing off-stream wetland areas and small side tributaries, these can provide important water storage locations within the catchment. With longer and more frequent dry-spells projected for the Otago region, these areas enhanced through stream naturalisation can increase the resilience of freshwater resources during increasingly frequent low-flow events.

Climate change mitigation

While riparian vegetation that do not meet the size requirements of the NZ ETS are not currently recognised for their climate change mitigation benefits in New Zealand, these areas along with farm shelter belts and other vegetation types are intended to be considered in the coming years within on-farm net-emission monitoring.

Acknowledging the high sustainability of New Zealand's agricultural sector, comparative to international producers, the common agricultural land uses of the Hakapupu lower and mid catchment do emit considerable volumes of greenhouse gases. Consequently, fencing and restoring riparian areas along the main waterways of Te Hakapupu would provide a net-carbon reduction benefit to support climate change mitigation. As referenced in the economic evaluation, the median sequestration values for planted riparian areas are estimated at 3.4 tonnes CO_2 per hectare per year. Although these areas provide a comparatively low sequestration rate (compared to pinus radiata forest for example), when coupled with other emission reduction practices, riparian vegetation may provide an important contribution to achieving on-farm or regional net-carbon zero objectives.

5.2.7 Is river naturalisation consistent with consenting requirements and key legal or policy considerations?

Land ownership characteristics

Based on analysis which captured parcels of land within a 10m buffer of the reaches of the streams and rivers where it is proposed to undertake naturalisation activities, a total of 22 titles of land are affected, of which two are owned by the Crown. The remaining titles are privately owned.

Regulatory implications

Based on the current high-level understanding of the works associated with the NbS intervention of river and stream naturalisation in the Hakapupu catchment, it is anticipated that the works might entail:

- Removal of existing vegetation (which may or may not be pest plant species, but is assumed that no indigenous vegetation will be removed)
- Planting of vegetation within riparian areas
- Ancillary earthworks
- Fencing to exclude stock from riparian areas

A summary of the potential consenting requirements associated with these activities under the relevant regulatory instruments is set out in in Appendix 6. Note that it is assumed that the works will not occur in proximity to any inland natural wetlands as defined in the NPS-FM, but that a detailed site survey should be undertaken to verify this. If natural inland wetlands are affected, then there could be consent requirements under the NES-F. Similarly, this NbS is not anticipated to trigger any consent requirements under the Otago Regional Plan: Water as it is unlikely to involve the types of activities managed under that plan (e.g. damming, diversion, discharge of water).

Policy considerations

An overview of the policy direction relevant to the river and stream naturalisation NbS intervention is set out below.

National Policy Statement – Freshwater

The objective of the NPS-FM is to ensure that natural and physical resources are managed in a way that prioritises:

- First, the health and wellbeing of water bodies and freshwater ecosystems
- Second, the health needs of people
- Third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

Related policies of relevance to this proposed NbS include that freshwater is managed as part of New Zealand's integrated response to climate change;[16] to ensure that the health and

[16] NPS-FM Policy 4

well-being of degraded water bodies and freshwater ecosystems is improved;[17] and that the loss of river extent and values is avoided to the extent practicable.[18]

National Policy Statement – Indigenous Biodiversity

The NPS-IB has an overarching objective of maintaining indigenous biodiversity across Aotearoa New Zealand so that there is at least no net loss in indigenous biodiversity after the commencement date of the NPS-IB. Related policies seek to promote and provide for the restoration of indigenous biodiversity, [19] and to promote increased vegetation cover in both urban and non-urban environments.[20]

Otago Regional Plan: Water

Objectives and policies in the Otago Regional Plan: Water seek to maintain or enhance the natural and human use values associated with Otago's lakes and rivers, as listed in Schedules 1A, 1B and 1C to the regional plan; [21] as well as the spiritual and cultural beliefs, values and uses of significance to Kai Tahu in Schedule 1D of the plan. [22] The provisions of public access long the margins of lakes and rivers is recognised; [23] as well as maintaining or enhancing the amenity values associated with these margins.[24]

Most of the related policies address water management issues, but Policy 5.4.13 seeks to encourage and support community initiatives that assist in the maintenance or enhancement of lakes and rivers and their margins. [25]

Dunedin District Plan

Objectives and policies in the Dunedin District Plan seek to maintain or enhance biodiversity values, including by encouraging conservation activity in all zones through the district. [26] Objective 16.2.3(f) seeks to maintain or enhance the rural character values and amenity of the rural zone, including by including extensive areas of indigenous vegetation and habitats for indigenous fauna. [27]

Waitaki District Plan

The Waitaki District Plan identifies ongoing modification and degradation of nature conservation values in the district as one of the key issues within the Rural parts of the district.[28] Related objectives seek to maintain biodiversity, nature conservation values and ecosystem functioning; as well as the quality of water, wetlands, lakes, rivers, and their margins. [29]

Overall, river and stream restoration would be generally consistent with the policy direction of the NPS-FM; Regional Plan: Water; the Waitaki District Plan; and the Dunedin District Plan

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[17] NPS-FM Policy 5
[18] NPS-FM Policy 7
[19] NPS-IB Policy 13
[20] NPS-IB Policy 14
[21] Otago Regional Plan: Water, Objective 5.3.1
[22] Otago Regional Plan: Water, Objective 5.3.2
[23] Otago Regional Plan: Water, Objective 5.3.5
[24] Otago Regional Plan: Water, Objective 5.3.4
[25] Otago Regional Plan: Water, Policy 5.4.13
[26] Dunedin District Plan Objective 10.2.1 and Policy 10.2.1.5
[27] Dunedin District Plan Objective 16.2.3(f)
[28] Waitaki District Plan Issue 8
[29] Waitaki District Plan Objectives 16.9.2(1) and (2)

5.2.8 Summary of river naturalisation as a nature-based solution

Opportunities

- This NbS intervention would stabilise stream banks and intercept runoff to reduce in stream contaminants.
- Naturalisation of riparian areas would potentially create suitable habitat for indigenous freshwater species, allowing for larger population sizes species and could bolster mahika kai values.
- With larger riparian setback areas, river naturalisation can be developed into productive zones, offering landowners opportunities to diversify their income, such as through productive riparian farming or other sustainable land uses.
- River naturalisation would enhance the natural landscape character and aesthetic values of lower and mid catchment areas.

Challenges

- Most riparian vegetation is currently excluded from NZ ETS and on-farm systems as recognised carbon sink.
- Without cost-benefit sharing or realisation of nature-based market opportunities, such as productive riparian zones or carbon values, the retirement of productive farmlands would cause a loss of revenue.
- Many riparian tree / shrub species are slow-growing and will not mature for many decades.
- Would require action of up to 22 landowners to be implemented across all currently unvegetated waterways in the lower and mid catchment.
- Has less potential to actively mitigate flooding related risks than the other two NbS presented in this report.

5.3 WETLAND RESTORATION AND CONSTRUCTION

The NbS intervention of wetland restoration and construction in Te Hakapupu/Pleasant River catchment, including at the northern and western extent of the existing wetland estuary, would seek to mitigate the effects of extreme rainfall induced flood hazards primarily through the provision of suitable areas substantial enough to accommodate and retain flood water.

Figure 17: Possible application of wetland restoration and construction in a typical catchment

5.3.1 How does wetland construction and restoration contribute to flood mitigation in the catchment?

In reference to the drivers of flooding and associated hazards within the catchment, this NbS would effectively adapt to reduce the experienced impacts of flood events through the following means:

Managed Retreat: Managed retreat of built infrastructure and primary production land uses vulnerable to the effects of flood hazards in the lower reaches of the catchment, predominantly located on historically drained and reclaimed wetland areas where flood waters are naturally predisposed to flow and pool. Retreat of these values to less flood prone locations would effectively reduce the hazard exposure and the subsequent hazard risk profile for infrastructure, people, and livelihoods.

Accommodate: Restoration and construction of wetland area located in historically drained and reclaimed wetland areas where flood waters are naturally predisposed to flow and pool would provide the landscape function of accommodating flood flows through retention and detention.

Accommodation of flood flows would reduce the vulnerability of surrounding people, infrastructure, and livelihoods to the effects of surface flooding, providing greater capacity to buffer the effects of extreme rainfall events as they increase under climate change scenarios.

Additionally, with properly constructed and maintained sediment ponds at inlet locations, this NbS can also serve to accommodate sediment and contaminants coming down the catchment, reducing the exposure of the lower estuary wetland complex to the flood-related effects of sediment inundation.

While wetland restoration and construction is considered as an approach to manage flood extent, the scale and depth of flooding in the 100-year ARI event in Te Hakapupu/Pleasant River Catchment suggest that the results will depend on where this storage is provided (and what scale of flood reduction would be targeted).

A large volume of storage would be necessary to achieve a material reduction, given that there are flood depths of more than 1.5m across most of the floodplain. In addition, flows are entering the main floodplain from a number of different reaches means that multiple basins could be necessary across the catchment.

5.3.2 How does wetland construction and restoration contribute to landscape amenity value, character, and recreation opportunities?

The wetland restoration and construction NbS intervention would seek to restore the existing Te Hakapupu/Pleasant River estuary wetland complex and create additional wetlands. The existing estuary wetland complex covers approximately 84 ha which would be expanded to approximately 140 ha in this NbS intervention. As part of this NbS intervention, wetland areas and margins will also be planted with native riparian species.

Existing character and values

The existing Te Hakapupu/Pleasant River estuary wetland complex is identified as a Regionally Significant Wetland and a Significant Natural Feature and an Area of Significant Nature Conservation Value under the Waitaki District Plan.

The 2015 Natural Character and Outstanding Natural Features and Landscapes Assessment for Otago's coastal environment (the 2015 Natural Character and Landscape Assessment) [30] identifies the estuary as a place of significance to local Maori including a highly significant archaeological site on the spit. However, while this wetland complex contains attributes that contribute to natural character, its inland extent is largely characterised by increased modification in the form of drainage and reclamation for improved pasture and is under pressure from invasive weed species, grazing, and alteration of natural flow characteristics. Some riparian planting is being undertaken through the Toitū Te Hakapupu project.

The 2015 Natural Character and Landscape Assessment finds that the estuary has high – medium landscape and natural character values. The higher ratings are particularly at its eastern (mouth) end with low – moderate values in its upper (inland) reaches).

[30] Coastal Environment of Otago: Natural Character and Outstanding Natural Features and Landscapes Assessment, Dunedin City Section Report, 28 April 2015, prepared by Mike Moore et al

Potential benefits

This NbS suggests to restore and expand Te Hakapupu/Pleasant River estuary wetland complex. This will buffer the impacts of flood flows entering the estuary wetland complex, better protect and increase the level of indigenous planting and habitat and assist with intercepting and treatment of suspended sediments and other contaminants. Restoring and expanding the existing estuary wetland complex will enhance the legibility and expressiveness of this natural landscape feature, the level of naturalness, which is currently modified, aesthetic values, and both the abiotic and biotic aspects of natural character, which have been degraded.

Under the implementation of this NbS intervention, the important wetland habitats and ecosystems found in the estuary wetland complex will be better protected from floods and sedimentation, with improvements in water clarity and reduction in channel modification together with restoration of the riparian margin, all increasing levels of natural character. Biodiversity benefits as a result of the planting of indigenous, riparian species will also enhance physical landscape values of the wetland complex as well as contributing to its natural character values.

The significance of Te Hakapupu/Pleasant River estuary to Kati Huirapa ki Puketeraki is identified in the 2015 Natural Character and Landscape Assessment as relating, among other things, to its importance as habitat for birds and Mahika kai values. This NbS intervention provides an opportunity to enhance these ecological and mahika kai values for tangata whenua which would result in a positive outcome for the feature’s associative landscape values. With the wetland restoration and construction, particularly the riparian planting proposed, amenity values associated with this estuary, wetland complex and its margins will also be enhanced.

Figure 18: Slope Hill wetland area planting. Source: Whakatipu Reforestation Trust

5.3.3 What are the potential biodiversity benefits, adverse effects, and practicalities of wetland construction and restoration in the catchment?

Biodiversity benefits & challenges

While the catchment already contains a relatively large area of estuarine wetland, areas of freshwater wetland habitat are currently far more limited in extent. The freshwater wetlands are typically small and potentially vulnerable, as they are largely surrounded by more intensive human activities and land uses.

A very large (c.140 ha) constructed and restored freshwater wetland would provide habitat for greater ranges and / or larger population sizes of indigenous flora and fauna. Targeted works could bolster desired Threatened, At Risk, and locally uncommon plant populations or support particular fauna species of ecological, cultural, or conservation importance within the catchment.

Where they sit low in the catchment, freshwater and brackish wetlands often provide important 'overflow' habitat. These 'overflow' habitat areas can be used seasonally or temporarily by coastal and estuarine species during high tide or climate conditions that reduce feeding habitats in the coastal environment, therefore benefitting coastal species as well. Additionally, increased wetland extent provides flow buffering for downstream waterways during flood and drought conditions, and open water areas provide refugia for aquatic species.

Constructed wetlands are often highly invadable by aggressive pest species, including plants (e.g., willows, alders), and tolerant fish species (e.g., rudd, perch). Whilst upfront design can reduce risk, ongoing and potentially costly pest control may be required if the desired outcome is to support indigenous species. Where constructed wetlands receive large sediment inputs from the upper catchment, this may 'choke the system' and prompt periodic maintenance and dredging. This risks additional cost, substantial mobilisation of sediment into downstream waterways, and loss of flora and fauna habitats that have established in the interim. This can be minimised by construction of forebays or implementation of additional measures to reduce sediment runoff in the first instance.

Practicalities of implementation

Wetland construction at the scale proposed in this NbS intervention is technically feasible in terms of design and construction but would be a large undertaking. Although, suitable land of existing low ecological value (productive farmland) is available on which a wetland could be constructed. Ecological input into plantings, wetland design (in terms of desired water levels and range, special features, and fish habitat and passage), and effects assessment for consenting and permitting processes (in relation to bulk earthworks and general works in / around waterways) would be required.

Furthermore, to achieve beneficial outcomes for biodiversity values within Te Hakapupu/Pleasant River catchment, wetland creation adjacent to waterbodies will likely require robust construction erosion and sediment control measures to be in place. Such measures will help minimise temporary impacts on in-stream habitat quality caused by construction activities.

Newly constructed wetland habitat (e.g. bare soils and shallow standing water) is highly invadable by weeds (as noted above). Therefore, very large-scale indigenous plantings to rapidly establish a desirable vegetation cover will be needed. The scale of plantings required would need several years lead-in time for a specialist nursery to propagate.

5.3.4 What are the high-level costs of the establishment and maintenance of wetland construction and restoration in the catchment?

Establishment & maintenance costs

Establishment and maintenance of wetland restoration and construction can vary significantly depending on the site characteristics and associated pressures, as detailed in Table 6.

Table 6: Indicative cost per hectare (2020) to establish and maintain a new wetland area if all works were to be undertaken by contractors at commercial rates. Summarised from Tanner *et al,* 2022. Note, these estimates exclude consent-related costs.

	INDICATIVE COST	$/HA (EXCL. GST)	NOTES
SITE SURVEY AND WETLAND DESIGN	Lump sum	$3,000 - $7,000	Survey of wetland site and design, including positioning of inlet and outlet structures, treatment basins and estimate of excavation works
EARTHWORKS	$6.25 per m^2 of wetland surface are for initial site clearance. $15 per m^3 for site excavation	$110,000 - $130,000	Includes excavation and re-laying of topsoil to form wetland base for planting, and construction of a suitable weir and outlet structure at downstream end. Excludes provision for fish passage structures
FENCING	$5 - $10 per l/m	$1,000 - $5,000	Assumes optimised wetland shape to minimise fence length
PLANT PURCHASE	$1.80 - $5 per plant	$25,000 - $60,000	2.04 plants per square metre (0.7 m spacings) within the wetland area to be flooded; all plants purchased from commercial nurseries
PLANTING	$2 - $3 per plant	$28,000 - $43,000	Assumes planting is done by commercial planter
REPLACEMENT PLANTING	$1.80 - $5 per plant	$2,500 - $5,000	5% mortality assumed; includes plant purchase and planting
PROJECT MANAGEMENT	$1 per m^2 of wetland	$10,000	Earthworks and planting supervision
MAINTENANCE	Lump sum	$2,000 - $4,000	Per annum. Assumes bi-yearly clean-out of sedimentation pond
TOTAL COST PER HA		$175,000 - $260,000 per hectare	

The locations identified for wetland restoration and construction as a NbS to flood hazard mitigation, in alignment with the wider Te Toitū Te Hakapupu restoration project, lend themselves to a number of cost reduction opportunities, including:

EARTHWORKS: Locating the wetlands within the historical Te Hakapupu/Pleasant River wetland area with natural drainage channels will likely require less earthworks to create the wetland area.

PLANT PURCHASING: Sourcing of suitable plant species for wetland and riparian areas may be selectively sourced or propagated from neighbouring wetland and riparian areas. Additionally, suitable plant species may already be present in the proposed locations given their tendency for naturally accommodating flood flows, in which case, simply removing grazing pressure and controlling weed species may be sufficient to enable those remanent plants to expand across the wetland area naturally. Alternatively, crowd sourcing mechanisms such as 'Trees that Count' could be applied to provide funding for plant purchase.[31]

PLANTING: Planting efforts can be supported by using community groups, public planting days, or facilitating corporate volunteer planting days.

Following the construction and restoration of wetland areas, a well-established wetland should incur only minor maintenance costs. Maintenance costs, particularly in a catchment such as Te Hakapupu / Pleasant River, will include the maintenance of the sedimentation ponds that function to intercept and process suspended sediments before entering the wider estuary wetland complex.

Sediment accumulation within wetland ponds should be regularly monitored, particularly during upper catchment harvest periods and heavy rainfall events. Removal of accumulated sediments should be conducted when the sediment ponds are half full of accumulated sediments. This will ensure the wetland may continue to optimally function and does not resuspend stored sediments during extreme rainfall flood events.

Land use change costs

Wetland construction and restoration of an area large enough to successfully accommodate flood flows within Te Hakapupu catchment would require the retirement of existing productive agricultural landholdings in the lower catchment.

Landholdings identified in the NbS intervention for wetland construction and restoration generally occupy Land Use Class 2 for Land Use Capability in the New Zealand Land Resource Inventory tool, primarily used for beef farming. Sheep, beef, and grain farming are of particular importance within the Otago Region and Waitaki District, adding approximately $530 million of value to the regional economy and $70 million of value to the district economy (Yang *et al.* 2023). On average, farm sale prices for the Otago Region between March and May 2024 were approximately $17,370.00 per hectare.[32]

Land use change benefits

Whilst requiring land use change of existing productive agricultural landholdings, reducing income revenue for the landowner, wetland restoration and construction does offer financial opportunity through nature-based market mechanisms – namely, blue carbon credits and biodiversity credits. These nature-based markets are a type of 'green financing', used to encourage and facilitate private investment and provide income incentives to deliver NbS.

- **Blue carbon credits** refer to the carbon sequestered and/or stored in coastal and marine ecosystems, which can be used to offset carbon emissions.

[31] www.treesthatcount.co.nz
[32] Published by Statista Research Department, Jul 15, 2024

- **Biodiversity credits** refer to measurable biodiversity co-benefits provided by a project or activity, which can be used as an offset to support 'nature-positive' claims.

Although a relatively nascent market a not currently recognised under the New Zealand Emissions Trading Scheme (NZ ETS), recognition and financial return for high quality blue carbon and biodiversity credits through the Voluntary Carbon Market (VCM) is quickly gaining momentum internationally. Accordingly, interest in these nature-based markets is building within New Zealand, with collaborative effort across government, iwi, non-government organisations, researchers, and landowners to share information and create market opportunities (Jacobs, 2024).

Initial analysis of New Zealand blue carbon opportunity estimates New Zealand's current national blue carbon stock at approximately 2.66-3.76 megatonnes of carbon, with a likely carbon sequestration rate of 50,000-260,000 tonnes of CO_2 per annum (Ross *et al,* 2023). As reference, an NZU carbon credit (representing one tonne of carbon removed and stored) trades at $61.80 at time of writing. Recent research into blue carbon market activity indicates that there is the potential demand for New Zealand sourced blue carbon credits from both domestic and international buyers, with demand anticipated to increase in line with global trends (Claes *et al,* 2022). While complex land tenure and carbon rights present a key challenge for recognising blue carbon credits in New Zealand, as this NbS intervention considered the restoration of wetland areas on existing land tenure as opposed to public land and waters. Accordingly, many of the tenure-related challenges may not be experienced.

Additionally, when undertaking NbS development rather than solely pursuing carbon sequestration outcomes, the generation of carbon credits can also deliver biodiversity co-benefits. These biodiversity benefits may be applied to support carbon credits from NbS to yield a premium price (well above the average NZU trading price) or be recognised as standalone biodiversity credits. The potential price premium added by biodiversity credits reflect the positive narrative that can be used in corporate sustainability reporting and product marketing. The Ministry for the Environment recently consulted on the opportunity to facilitate growth of biodiversity credit systems in New Zealand, receiving overall strong support (Mfe, 2024).

Figure 19: Thomsons wetland planting, Otago. Source: Manuherekia Catchment Group

5.3.5 What are the potential impacts, benefits, and trade-offs wetland construction and restoration may have in the catchment, alongside productive rural land uses and as part of Kāti Huirapa ki Puketeraki's takiwā?

The NbS intervention of wetland restoration and construction align with the identified values and strategies of the Toitū Te Hakapupu Catchment Action Plan (CAP) (Ahikā, 2023). The relevant values and strategies are detailed below.

Value 1: Waterways

Value 1 of the draft Toitū Te Hakapupu CAP recognises that 'Waterways in the catchment and the estuary wetland complex provide important habitat and eco-system services'. However, these important habitats and ecosystem services are under pressure from the effects of erosion and sedimentation, particularly from pastoral farming and plantation forestry operations within the catchment reducing water quality and causing degradation to the estuary wetland complex.

The NbS intervention of wetland restoration and construction would contribute benefits towards the enhancement of Value 1, specifically aligning with the following draft CAP strategies:

- S1A. Levels of contaminants and sediment entering waterways and estuary wetland complex will be reduced, in accordance with target attributes states set out in the Land and Water Regional Plan (LWRP)
- S1E. Natural functioning of the estuary wetland complex will be enhanced, where there is landowner agreement

The restoration and construction of wetland areas identified in the catchment can support reducing the contaminants and sediment entering the estuary wetland complex. An appropriately maintained wetland occupying 1-5% of the catchment area, with sediment ponds developed at the inlet of wetland areas, on average should remove 50-90% respectively of the long-term sediment inputs through a range of physical, chemical, and biological processes (Tanner *et al,* 2021).

Suspended sediments being transported through the catchment from upper catchment operations and stream bank erosion are primarily removed in a constructed wetland by settling and deposition. Larger sand and soil particles will deposit in the inlet sediment pond, while the finer silt and clay sediments will be dispersed through the wetland where they may be removed through biological and chemical processes.

Additionally, dissolved nitrates present in agricultural runoff from pastoral farming activities can be removed by a restored and constructed wetland through biological processes, such as microbial de-nitrification and plant uptake. For cool climate zones, such as the Otago Region, the median nitrogen removal rates for a well-maintained wetland occupying 1-5% of catchment area range from approximately 20% to 40% respectively (Tanner *et al.* 2021).

The NbS intervention of wetland restoration and construction would also support enhancement of the estuary wetland area by increasing the spatial extent of the wetland area within its historic natural extent. At 84 ha, the estuary wetland complex has significantly reduced in size from its likely historic extend, to approximately 2% of its historic size. By considering the extension of the estuary wetland complex at its northern and western present-day extend, a wetland restoration and construction NbS would seek to enhance the natural functioning of the complex. Growth of the wetlands within these locations would serve to increase the wetlands natural function of removing and processing suspended sediments and contaminant being transported downstream from developed productive lands.

Value 2: Biodiversity

Value 2 of the Toitū Te Hakapupu CMP recognises that 'Biodiversity within the catchment provides important habitat, ecosystem services, and landscape amenity'. However, these important habitats, ecosystem services, and landscape amenity are under pressure from land clearance, modification, and pest and weed species in the catchment. The NbS intervention of wetland restoration and construction would contribute benefits towards the enhancement of Value 2, specifically aligning with the draft CAP strategy:

- S2A. Existing remnants of indigenous vegetation and wetlands will be identified, protected, and enhanced

In alignment with S2A, the NbS intervention of wetland restoration and construction would contribute to the increase of indigenous vegetation and wetland area in the catchment. Through either the dedicated sourcing and planting of indigenous plant species or fencing and maintenance to facilitate the natural expansion of remnant indigenous wetland plant species, wetland restoration and construction delivered at scale within Te Hakapupu would significantly increase indigenous vegetation and wetland area. By connecting restored and constructed wetland areas to the existing Estuary Wetland Complex, protection and enhancement of indigenous vegetation and wetland area would likely increase the habitat availability for important biodiversity values.

Value 3: Cultural significance

Value 3 of the Toitū Te Hakapupu CMP recognises that 'the catchment is part of Kati Huirapa ki Puketeraki's takiwā and is culturally significant', however, mana whenua have lost access to large parts of the catchment, and cultural values are degraded. The NbS intervention of wetland restoration and construction would contribute benefits towards the enhancement of Value 3, specifically aligning with the following draft CAP strategy:

- S3A. Water quality and habitat will be protected and enhanced with a focus on mahika kai and taonga species so that abundance is sufficient to support cultural practices

The NbS intervention of wetland restoration and construction seeks to enhance the mahika kai values of Te Hakapupu/Pleasant River Estuary Wetland Complex. Historically, the estuary wetland complex has been rich source of mahika kai for Puketeraki whānau, with freshwater migratory species such as Kōkopu, Īnaka, and Tuna being found in the catchment's freshwater environments and Pātiki, Kahawai, and Aua being found in the marine estuary. Wetland restoration and construction in connection to the existing estuary wetland complex would seek to enhance the habitat availability and quality for mahika kai species present. Additionally, by increasing the extent of the estuary wetland complex further inland, the NbS would help increase the resilience of mahika kai to the effects of sea-level rise, coastal inundation, and increased salinity stress, noting that Tuna, Banded kōkopu, and Īnaka are all ranked highly vulnerable to the effects of climate change (Egan *et al.* 2020).

5.3.6 How does wetland construction and restoration adapt to and/or help mitigate the effects of climate change in the catchment?

Climate change adaptation

Wetland restoration and construction in the lower catchment areas identified in this NbS intervention, would help increase the resilience of the catchment to the future effects of climate change. As illustrated in Map 6, the lower catchment is exposed flood hazards associated with coastal inundation.

With minor vertical land movement (0.7± 2.2mm/year) at the estuary mouth, relative sea-level rise is projected to occur in line with national sea rise rates, with 0.21m of relative sea-level rise projected by 2050 and 0.74m by 2100 (under scenario SSP5-8.5 50th percentile). As a result, the catchment's estuary wetland complex is likely to be exposed to increasing salinity stress and coastal inundation from the effects of more frequent and intense coastal storm surges, causing flooding of inland areas.

By locating wetland construction and restoration NbS within areas exposed to future coastal inundation during storm surge events, this NbS serves to increase climate resilience through two key approaches:

- Reducing the exposure of existing productive agricultural landholdings to more frequent and severe coastal inundation events through the managed retreat of farming activities and infrastructure away from these areas.
- Providing additional habitat for wetland biodiversity values unable to cope with increasing salinity stress from rising sea levels to accommodate migration further inland, less exposed locations.

Wetland restoration and construction within these locations, effectively increasing the inland extent of the estuary wetland complex, will help buffer the effects of relative sea level rise and avoid the 'coastal squeeze' of critical biodiversity values within the catchment. Furthermore, this NbS would likely increase the connectivity between coastal, estuary, and wetland ecosystems, allowing greater potential for the gradual retreat and reorganisation of habitats to suit the changing environment over time.

Climate change mitigation

As a NbS, changing land use from agricultural to wetland would provide a net-carbon benefit. Acknowledging the high sustainability of New Zealand's agricultural sector, comparative to international producers, on average, sheep and beef farming in New Zealand emits 3.6 tonnes of greenhouse gases per hectare per year (between 0.16-7.1 tonnes/ha/year) (MfE, 2024). As discussed in the Land Use Change Cost and Benefits section, restoration and construction of wetlands as a NbS presents climate change mitigation opportunities, through the sequestration and storage of carbon dioxide (CO_2).

While significant gross reductions in gross greenhouse gas emissions is required to mitigate the effects of climate change, growth of permeant CO_2 removals is required to avoid the most severe effects of climate change. Wetlands are considered efficient carbon stores, with the ability to store significant volumes of carbon in plant biomass and sediments.

Although the specific carbon removal capability of wetlands still requires further research and site-specific analysis to quantify, an initial analysis of national blue carbon stocks (across wetland, mangroves, salt marches, and sea grass) estimates current national carbon at approximately 2.66-3.76 megatonnes of carbon, with a likely carbon sequestration rate of 50,000-260,000 tonnes of CO_2 per annum (Ross *et al,* 2023).

5.3.7 Is wetland construction and restoration consistent with consenting requirements and key legal or policy considerations?

Land ownership characteristics

Of the approximate size identified within the wetland restoration and construction area; there are 24 titles of land which are owned by 17 landowners. Two of those owners are public entities – the Otago Regional Council and Waitaki District Council. The remaining landowners are private owners.

Regulatory implications of NbS

Based on the current high-level understanding of the works associated with NbS intervention of wetland restoration and construction within the Hakapupu catchment, it is anticipated that the works might entail:

- Restoration and enhancement of the existing wetland
- Construction of new wetland areas
- Associated earthworks
- Planting of vegetation (potential within existing wetlands and riparian areas)
- Removal of existing vegetation (which may or may not be pest plant species, but is assumed that no indigenous vegetation will be removed)
- Potential take, damming, or diversion of water
- Discharge of water

A summary of the potential consenting requirements associated with these activities under the relevant regulatory instruments is set out in Appendix 6.

Policy considerations for NbS

An overview of the policy direction relevant to the NbS intervention of wetland restoration and construction is set out below:

National Policy Statement – Freshwater

The objective of the NPS-FM is to ensure that natural and physical resources are managed in a way that prioritises:

- First, the health and wellbeing of water bodies and freshwater ecosystems
- Second, the health needs of people
- Third, the ability of people and communities to provide for their social, economic, and cultural well-being, now and in the future.

Related policies of relevance to this proposed NbS include that freshwater is managed as part of an integrated response to climate change;[33] and that there is no further loss of natural inland wetlands, their values are protected, and their restoration is promoted. [34]

National Policy Statement – Indigenous Biodiversity

The NPS-IB has an overarching objective of maintaining indigenous biodiversity across Aotearoa New Zealand so that there is at least no net loss in indigenous biodiversity after the commencement date of the NPS-IB. Related policies seek to promote and provide for the restoration of indigenous biodiversity, [35] and to promote increased vegetation cover in both urban and non-urban environments.[36]

Otago Regional Plan: Water

Objectives and policies in the Otago Regional Plan: Water seek to recognise, sustain, maintain and enhance wetlands within the region. [37] This includes by identifying Regionally Significant Wetlands in accordance with specific criteria;[38] and promoting the conservation, creation and reinstatement of wetland areas. [39] Maintaining the passage of fish, and improving the passage of fish, is also recognised as an objective which could be relevant in relation to this NbS depending on the ultimate design of the proposal. [40]

Restoration of the ecological and cultural values of degraded waters is recognised as a fundamental principle of Māori environmental management in the Otago Regional Plan: Water.[41] Similarly, the Otago Regional Plan: Water notes that many wetlands of significance to Kai Tahu have been lost, and their loss could continue. [42]

Dunedin District Plan

Objectives and policies in the Dunedin District Plan seek to maintain or enhance biodiversity values, including by encouraging conservation activity across the district. [43] The clearance of vegetation within setbacks from wetlands is managed to ensure biodiversity values are maintained or enhanced and that there is no reduction in the extent of natural wetlands. [44]

Waitaki District Plan

The Waitaki District Plan identifies ongoing modification and degradation of nature conservation values in the district as one of the key issues within the Rural parts of the district.[45] Related objectives seek to maintain biodiversity, nature conservation values and ecosystem functioning; as well as the quality of water, wetlands, lakes, rivers and their margins. [46]

Overall, wetland restoration and construction would be generally consistent with the policy direction of the NPS-FM; Regional Plan: Water; the Waitaki District Plan; and the Dunedin District Plan.

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[33] NPS-FM Policy 4
[34] NPS-FM Policy 6
[35] NPS-IB Policy 13
[36] NPS-IB Policy 14
[37] Otago Regional Plan: Water, Objectives 10.3.1 and 10.3.2
[38] Otago Regional Plan: Water, Policies 10.4.1 – 10.4.2.A
[39] Otago Regional Plan: Water, Policy 10.4.6
[40] Otago Regional Plan: Water, Objective 8.3.4
[41] Otago Regional Plan: Water, Clause 4.13.8
[42] Otago Regional Plan: Water, Clause 4.13.6
[43] Dunedin District Plan Objective 10.2.1 and Policy 10.2.1.5
[44] Dunedin District Plan Policy 10.2.1.Z
[45] Waitaki District Plan Issue 8
[46] Waitaki District Plan Objectives 16.9.2(1) and (2)

5.3.8 Summary of wetland restoration and construction as a nature-based solution

Opportunities

- This NbS intervention at sufficient scale would effectively accommodate excess flood flows in areas amenable to hydrological restoration and reduce contaminants entering the lower estuary wetland complex.

- With the creation of water retention and detention ponds, wetland areas can buffer downstream flows during flood and drought conditions.

- Provide habitat for greater ranges and larger populations of native species, including mahika kai species, and support the retreat of aquatic species from the impacts of sea-level rise.

- Wetland restoration and construction can provide for blue carbon and biodiversity credit opportunities in emerging markets by creating measurable enhancements in carbon storage and biodiversity values.

- The NbS is broadly consistent with national and local policy and planning direction, although requiring potentially complex consenting requirements when working in waterways.

Challenges

- With sedimentation pressures in the catchment, wetland areas would require bi-annual maintenance of sediment ponds to ensure functionality is retained.

- Wetland areas can often be highly invaded by aggressive pest plant and fish species, diminishing biodiversity values.

- Without cost-benefit sharing or realisation of nature-based market opportunities, would cause loss of economic value to landowner.

- Would require action of up to 17 landowners to be implemented across lower catchment.

WHAT HAVE WE LEARNT?

Credit: Boffa Miskell Ltd

6. WHAT HAVE WE LEARNT?

6.1 FEASIBILITY OF NATURE-BASED SOLUTIONS FOR FLOOD MANAGEMENT

NbS present an integrated solution to effectively address the interconnected challenges of flood hazards, biodiversity loss, and land degradation within Te Hakapupu catchment. As a large and highly modified coastal Otago catchment, Rapid Flood Hazard Modelling developed for this feasibility study projects flood waters to be quickly transported from the steeper upper catchment areas, along well-entrenched waterways, to cause surface flooding in historically drained wetland areas in the lower catchment. With the upper catchment of Te Hakapupu dominated by exotic plantation forestry and mid catchment predominantly pastoral farming land uses, flood waters transport contaminants, causing additional flood-related impacts as they discharge into the ecologically and culturally significant Te Hakapupu Estuary Wetland Complex

The NbS tested in this feasibility study considered interventions that worked with the natural landscape and catchment hydrology to address flood hazards in a sustainable way and at scale. The NbS tested were all assessed to effectively mitigate flood-related hazards within the catchment, while possessing the potential to deliver benefits to biodiversity values, cultural values, natural landscape character, and local community catchment management plan targets. Additionally, these NbS were assessed to broadly align with national and local policy and planning requirements, although likely requiring potentially complex consenting requirements particularly when working in water ways.

While NbS interventions have been tested to be technically feasible and beneficial for addressing flood hazard and other challenges experienced within Te Hakapupu catchment, their potential use likely faces significant social and economic barriers. Requiring cooperation of over twenty or more individual landowners, all NbS require a substantial change in land use from productive agricultural or forestry uses.

Given the flood-related hazards are modelled to occurring in the mid and lower Te Hakapupu catchment locations, under current governance practices the direct economic costs incurred to individual landowners in implementing a NbS do not often generate a direct individual benefit. This is expected to create inequities in sharing the costs and benefits across effected landowners within the catchment. The sharing of economic costs and benefits is a common challenge experience by NbS practitioners globally and requires careful attention to ensure NbS are used sustainably and equitably.

Accordingly, any undertaking of NbS for flood hazard mitigation within Te Hakapupu catchment must first ensure that the governance framework for any intervention is well defined and economic incentives are available through alignment with nature-based market opportunities as much as practicable.

6.2 FEASIBILITY STUDY KEY FINDINGS

NbS are technically feasible in Te Hakapupu/Pleasant River catchment

Nature based solutions are technically feasible as methods for the management of flooding and associated hazards in Te Hakapupu/Pleasant River catchment and across the wider Otago region. NbS will work to influence the natural processes across the catchment to effectively control and accommodate floodwater, and their use should be promoted as a method of flood risk mitigation.

Landcover management in the upper catchment is the first step

Implementing land cover management NbS in areas of the upper Te Hakapupu/Pleasant River catchment is crucial for reducing flood-related risks, which tend to increase during forestry activities, such as forestry harvesting and replanting. While addressing the current level of hazards is essential, it is equally important to prevent conditions from worsening. Without permanently restoring and maintaining the hydrology of the upper catchment, through land management practices, the flood risk in the Te Hakapupu/Pleasant River catchment is expected to increase significantly, recurring in line with harvest and replanting 'windows of vulnerability'.

NbS work most successfully when applied at scale

In a large catchment like Te Hakapupu/Pleasant River, to sufficiently manage flooding and associated hazards NbS should be applied at a suitably large scale. NbS are most effective when implemented over larger areas or broader contexts, and while small-scale NbS projects can be useful, scaling them up maximises their ecological, economic, and social benefits. This would require large land use changes from farming and forestry in Te Hakapupu/Pleasant River catchment. In general, small-scale interventions will cost more per hectare and generate less benefits that a large-scale intervention.

Integrated NbS provide enhanced benefits

Nature-based solutions (NbS), such as river naturalisation and wetland construction, need to function in an integrated manner, from Ki Uta Ki Tai (mountains to the sea), across the catchment, connecting with each other and with surrounding land uses. At scale, interconnected nature-based solutions are essential for effectively managing flood hazards, working as a cohesive network to maximise their impact. Integrated NbS also provide significant benefits for biodiversity, landscape, amenity, and recreation, while also contributing to regional climate change adaptation and mitigation goals.

Innovation is required to ensure NbS are economically viable

The current economic and funding framework presents one of the greatest challenges to NbS implementation across Te Hakapupu/Pleasant River catchment. The direct cost and financial burden to landowners of implementing NbS, coupled with the resulting loss of productive land currently used for forestry and farming, makes at large-scale NbS financially unviable for many forestry and farming landowners in the catchment.

To support large-scale adoption of NbS and to help landowners benefit financially from NbS, especially across areas of productive forestry and farming land use like Te Hakapupu/Pleasant River catchment, innovative economic approaches are needed. This will require strong governance and political backing, as well as economic support and financial assistance, from both the private and public sectors. This could involve financial incentives for landowners, such as payments for environmental benefits and cost sharing initiatives and programmes.

6.3 RECOMMENDED ACTIONS

The following actions are recommended to facilitate the practical implementation of NbS in Te Hakapupu/Pleasant River catchment and other similar catchments across the Otago region.

The recommended actions consist of actions that ORC can lead and deliver at a regional scale; however, most would benefit from engagement and collaboration with other parties, including central government agencies to ensure national consistency, financial institutions, and funding partners to help address economic barriers, and landowners, mana whenua, district council within the Otago Region and local communities to ensure local buy-in.

Action 1: Strengthen NbS governance and partnerships

Develop and apply robust governance and partnership approaches for NbS alongside landowners, businesses, mana whenua and financial institutions to ensure the costs and decisions for NbS design and implementation are shared fairly.

To support the national and regional policy direction relating to NbS use in the Otago region, NbS governance and partnership approaches should seek to achieve the following outcomes:

- Define how the direct costs and benefits from NbS that span different locations, land uses, tenures, and vested interests will be equitably shared
- Define how under-represented groups and effected people will be engaged throughout NbS development processes
- Identify private and public financial investment opportunities, including green bonds and sustainability-linked loans
- Define clear decision-making process and accountabilities for NbS development and ongoing maintenance, where NbS span different locations, land uses, tenures, and vested interests

The development and application of robust governance and partnership approaches for NbS that can be applied in the Otago region would help address the economic barriers that limit the practical feasibility of NbS use.

This recommended action would ensure that individual landowners are not overburdened by the costs of establishing and maintaining NbS on their land, particularly given the primary beneficiaries of NbS for hazard management are often not the direct landowner. Additionally, robust governance practices would ensure any economic benefits gained from NbS are appropriately attributed to the parties that invested their land, time, and money.

Action 2: Facilitate economic incentives for landowners

To address the potential economic impacts that may be experienced when landowners change land uses, particularly from changing primary production lands to NbS land uses (e.g. retiring productive farmland to become wetland), a model for economic incentives should be considered. Develop and implementing a model that provides economic incentives to landowners could include mechanisms such as payments for ecosystem services, grants, tax incentives, carbon credit sales and revenue from ecotourism.

Internationally, economic incentives are successfully used at national and regional scales to financially support landowners to undertake capital works and land management activities for the purposes of natural hazard mitigation and conservation.

Examples of these include:

- The Scottish Rural Development Programme, where government bodies offer funding packages for projects where land is used or maintained to provide benefits for water or biodiversity.[47] Funding packages are target high value areas to support landowners to undertake capital works and land management for environmental purposes, such as woodland afforestation. Funding is provided as either a one-off payment for capital works, or annual payments for specific land management options (e.g. floodplain management).
- The U.S Department of Agriculture's Agricultural Conservation Easement Programme helps landowners, land trusts, and other entities protect, restore, and enhance wetlands or protect working farms and ranches through conservation easements.[48] This supports landowners to restore and protect areas from the impacts of farming and development through the creation of easements. The government agency funds up to 100% of the easement value for the purchase of the easement and help funds restoration costs on the easement.

The development of similar economic incentive models for the Otago Region would provide significant benefits to overcoming the economic challenges currently facing NbS implementation. Additionally, the targeted application of a regional economic incentive model that focuses on areas of high risk or of high biodiversity value, could support the use of NbS in priority locations, helping to achieve other environmental benefits.

[47] Scottish Rural Development Programme (SRDP) - Agricultural payments: Common Agricultural Policy (CAP) - gov.scot
[48] Agricultural Conservation Easement Program | Natural Resources Conservation Service

Action 3: Promote nature-based credit markets

This recommended action aims to increase understanding and use of nature-based markets for ecosystem services, helping to attract private investment in NbS across Otago. One example is enabling private companies to "purchase" NbS and associated carbon and biodiversity credits to offset their carbon emissions.

To improve financial incentives for NbS and boost private investment in the region, efforts are needed to build greater recognition and trust in these nature-based markets for landowners. While central government is already working to enhance the New Zealand Emissions Trading Scheme (ETS) for afforestation, exploring other carbon removal methods, and supporting a biodiversity credit system, regional efforts will further advance these initiatives.

In addition, established catchment or landscape-scale restoration projects, like Toitū Te Hakapupu Restoration Project, could serve as pilot sites to test and scale nature-based credit market opportunities in New Zealand.

Actions to support use of nature-based credit markets at the Otago catchment scale could also include:

- Identification of biodiversity credit pilot opportunities for existing well-established landscape scale restoration project across the Otago region, along with the monitoring and reporting requirement likely required to meet biodiversity credit market verification standards.

- Assessment of afforestation carbon values across a catchment and identification of opportunities for carbon credits either through the New Zealand ETS or via credible Voluntary Carbon Markets.

- Building on the indicative outcomes from DairyNZ and NIWA's assessment of productive riparian areas, conduct an assessment at catchment or district scale of the potential applications of productive riparian areas on Otago farms to understand the likely costs, economic opportunities, and optimal application of establishing economically productive riparian buffer areas on farm.

- Catchment scale analysis of saltmarsh and wetland areas to understand the blue carbon stock currently held within the catchment wetland and estuarine environments, and blue carbons stock change potential under different wetland restoration and enhancement scenarios.

Using nature-based credit markets to encourage landowners to invest in NbS will be crucial for overcoming the economic barriers that currently limit the adoption and long-term maintenance of these solutions.

Action 4: Develop regional NbS policy, standards, and guidance

Otago NbS practice standards, guidance and policy should be developed to support private landowners to actively adopt and implement NbS on their own properties. Standardised NbS practice and guidance would ensure that NbS used by a landowner are applied consistently across the Otago region, allowing NbS to function in an integrated manner to deliver greater benefits. This includes providing comprehensive guidance for NbS planning, addressing the required consenting pathways to streamline implementation.

Examples of Otago NbS practice policy, standards, guidance could include:

- Identification of the common NbS that can be used to mitigate natural hazards experienced in the Otago region and within a catchment.
- Promoting benefits of wide scale application if NbS and embedding information regarding the outcomes that can be provided by NbS into relevant regional policy
- NbS design standards and criteria to inform how they are implemented
- Guidance of the relevant policy and consenting requirements for common NbS, particularly for interventions in and around waterways, and support to facilitate NbS planning progress through the relevant consenting pathways
- Links to available NbS design and implementation tools and resources, including regional GIS resources and funding opportunities.

Otago NbS practice policy, standards and guidance would help community users to ensure their NbS work cohesively across the catchment and are able to function in an interconnected way to generate greater benefits. Additionally, by providing NbS policy and planning guidance, NbS users would be supported to navigate the required consenting needs to implement NbS in alignment with national and local policy direction.

Action 5: Integrate NbS into catchment scale management and planning

Nature base solutions should be planned for and integrated within the Te Hakapupu Catchment Action Plan, and for other similar Otago region catchments through Integrated Catchment Management Planning (ICMP) processes.

ICMP's are intended to be tools for managing natural resources on a catchment scale, looking at the ecosystems and land uses from the mountains to the sea. Accordingly, the integration of NbS planning within ICM programmes will be effective to ensuring NbS are designed and enabled at the correct scale to address natural hazards and work cohesively with catchment land uses and community values.

Key aspects of NbS integration within ICMP processes could include:

- Hydrology modelling of the catchment to understand the flood hazard characteristics under a diversity of climate change scenarios and timeframes (including a do-nothing scenario). Scenarios should consider the impacts of extreme rainfall events, relative sea-level rise, and coastal inundation events to people, property, and ecosystems.

- Spatial analysis of the catchment to identify the location, extent, and type of remnant indigenous vegetation present in the upper, mid, and lower catchment. Remnant indigenous vegetation areas identified should be assessed to understand their potential for indigenous habitat expansion through protection and enhancement measures.

- Identification of the type, scale, and optimal locations of NbS required to effectively mitigate natural hazards present in the catchment. This should include identification of where NbS should be applied as a single large intervention, or where they can be applied as a series of smaller interconnected solutions.

Integration of NbS within ICM programmes will help ensure NbS interventions are planned and implemented at an appropriate scale, relative to the size of the catchment and magnitude of the hazards and are able to function in an interconnected way to generate greater benefits.

GLOSSARY & REFERENCES

Credit: Great South

7. GLOSSARY

Table 7: Glossary to key terms relating to Nature-based Solutions

TERM	DEFINITION
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects. (IPCC, 2022)
Biodiversity	The variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. (Convention on Biological Diversity, 2006)
Biodiversity Credits	A type of economic instrument that recognises in a consistent way projects or activities that provide positive outcomes for biodiversity, against which 'nature-positive' claims can be made. (MfE, 2023)
Blue Carbon	Blue carbon is the carbon stored in coastal and marine ecosystems. Coastal ecosystems such as mangroves, tidal marshes and seagrass meadows sequester and store more carbon per unit area than terrestrial forests and are now being recognised for their role in mitigating climate change. (IUCN, 2017)
Climate Change	A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC, 2022)
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected. (IPCC, 2022)
Green Infrastructure	A strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings (UNEP Glossary)
Grey Infrastructure	Term used to describe engineered water and hazard management structures such as reservoirs, embankments, pipes, pumps, water treatment plants, and canals (NIWA, 2024)
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. (IPCC, 2022)

Impact	The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial. (IPCC, 2022)
Maladaptation	Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead. (IPCC, 2022)
Nature	A holistic term that encompasses the living environment (te Taiao), which includes all living organisms and the ecological processes that sustain them. By this definition, people are a significant part of nature. This document uses the term ‘biodiversity’ to refer to biological diversity and ‘nature’ for the wider processes, functions, and connections in the natural environment, of which biodiversity is a part. (MfE, 2023)
Resilience	The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation. (IPCC, 2022)
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social, and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure, and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making. (IPCC, 2022)
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (IPCC, 2022)
Water Sensitive Urban Design	Water Sensitive Urban Design - an approach used in urban greening which adopts nature-based solutions (NBS) and ecosystem-based adaptation (NIWA, 2024)

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