Wetland Restoration: Advice on Policy Visions for Wetland Extent by 2050

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WETLAND RESTORATION

ADVICE ON POLICY VISIONS FOR WETLAND EXTENT BY 2050

AUGUST 2023

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EXECUTIVE SUMMARY

As part of the policy development workstream to implement the National Policy Statement for Freshwater Water Management 2020 (NPS-FM), Horizons' Policy Team is considering a policy vision for wetland state by 2050 to be potentially based on the following three scenarios:

1. By 2050, regional extent (ha) of wetland is doubled from current (2022)[1] extent (biodiversity outcome).
2. By 2050, regional extent (ha) of wetland is returned to the 1997[2] extent (biodiversity outcome).
3. By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome).

Horizons' Science team contracted The Catalyst Group to provide advice on the potential implications of the proposed policy scenarios from an implementation perspective and for water quality and indigenous biodiversity outcomes.

This report:

- Clarifies **definitions** associated with wetlands (**Section 1.2**).
- Presents an **evaluation** of the three proposed policy scenarios against criteria aimed to explore the framing, strategic direction, policy direction, and implementation aspects of the scenarios (**Section 2**).
- Further evaluates the proposed policy scenarios via **detailed responses** to specific questions posed by Horizons, informed by a **literature scan** with emphasis on material published in the last 20 years (**Section 3**).

Thus, this report can be read as being a report of two parts. First the high-level evaluation of the three scenarios, and second a deeper exploration of the potential implications of their implementation and the interplay between them. The latter section takes a strong focus on constructed wetlands arising from the emphasis on constructed wetlands as a proxy for water quality outcomes, the potential for conflating constructed wetlands and natural wetlands and the risks to indigenous biodiversity outcomes when doing so, and the nature of the specific questions underpinning this report. The two parts of the report are brought together in the final section which provides **recommendations** on the proposed policy scenarios specifically and for wetland policies more generally.

Key findings

- All three policy scenarios require reworking to improve relevance to and potential outcomes for indigenous biodiversity and water quality. In particular:
    a) Relying solely on extent limits potential to bring about indigenous biodiversity outcomes. A policy scenario that encapsulates the concept of ecological integrity is more appropriate.
    b) The proposed policy scenario targeted at water quality outcomes conflates (one) means with the end. It would be more meaningful to have a policy vision that describes the outcome being sought rather than restricting the use of attenuation tools to just one option (constructed wetlands).

[1] As there has not been an update to wetland extent data (Horizons pers. com.) 'current (2022)' extent is taken as the extent (7065 ha) published in 2007 to support the development of the One Plan (Maseyk 2007).

[2] Regional wetland extent data was not able to be obtained for 1996, but regional extent of freshwater wetlands at 1997 (8537 ha) was available (Denyer & Peters 2020) and assumed to be accurate for 1996.

- Constructed wetlands can be a useful attenuation tool for the purposes of nutrient management of agricultural run-off, but the effectiveness of constructed wetlands is variable, and it is not a straightforward undertaking. The potential for constructed wetlands as a nutrient management tool on-farm is as a supplementary, not an alternative, measure to source control, and when utilised alongside other nutrient management tools.
- Wetlands constructed for purposes of nutrient management and natural wetlands restored for the purposes of indigenous biodiversity outcomes are typically different in structure, composition, and function. They are not interchangeable.
- Wetland restoration and enhancement for indigenous biodiversity at the scale required will require the bringing together of multiple opportunities to deliver outcomes and courageous leadership to bring about a change in practice and to ensure indigenous biodiversity outcomes are not undermined by the parallel urgency to address water quality issues.
- All three policy scenarios have the potential to generate tensions, perverse outcomes, and/or detract from other policy priorities and directions; are locked into long-term (a generation) outcomes without short and mid-term targets.
- Implementation of all (or any) of the policy scenarios will be extremely challenging and will confront implementation barriers not dissimilar to any programmes requiring land use change. The construction, restoration, or enhancement of wetlands will be difficult, expensive, requires a long-term commitment and ongoing expenditure, and requires expertise and resources unlikely to be available to many landowners. The shift in land use and long-term resourcing commitment is likely to be politically challenging. Implementation will need a multi-pronged approach (spanning across policies) including greater understanding and communication of the value of wetland habitat to the farm system, and appropriate incentives and disincentives to drive necessary actions, and be underpinned by spatial planning.

Recommendations

Detailed recommendations are provided in Section 4 of the report and summarised here:

- **Adopt the interpretation** of constructed wetlands, wetland restoration, and wetland enhancement used in this report and **include definitions** for these terms in policy documents.
- **Rework the proposed policy scenarios**:
  a) For indigenous biodiversity outcomes, reframe the scenario to encapsulate ecological integrity.
  b) For water quality outcomes, reframe the scenario to focus on the end and not the means.
- **Redesign and resource the wetland restoration and enhancement programme** for indigenous biodiversity outcomes supported by a well-designed implementation plan that (among other things) is underpinned by systematic spatial conservation planning, includes multiple avenues to achieve outcomes (including iwi and hapū-led wetland restoration and enhancement initiatives), includes outcome monitoring and reporting.

- Constructed wetlands have great potential as a useful attenuation tool to improve water quality outcomes, and recommend the following to **facilitate appropriate use of constructed wetlands** in the appropriate place for the appropriate purpose:
    a) Manage expectations of performance of constructed wetlands.
    b) Utilise whole farm planning processes to determine appropriate attenuation tools and detail site-specific construction and maintenance work plans.
    c) Utilise existing guidance documents for constructed wetlands.
- **Recognise the level of resourcing required and that it will be ongoing.** This includes resourcing for strategic planning, research needs to fill knowledge gaps, programme oversight, and delivery of works.
- **Monitor and report on outcomes for water quality and indigenous biodiversity separately**, which should acknowledge but not conflate, co-benefits from constructed wetlands for biodiversity and from restored or enhancement wetlands for water quality outcomes.
- **Amend the One Plan** to provide for constructed wetlands and to exclude constructed wetlands from Schedule F.

Finally, we note that this report (in part or full) may be useful in contributing to the Freshwater Plan development Section 32 requirements.

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1. INTRODUCTION

As part of the policy development workstream to implement the National Policy Statement for Freshwater Water Management 2020 (NPS-FM), Horizons' Policy Team is considering a policy vision for wetland state by 2050 to be potentially based on the following three scenarios:

1. By 2050, regional extent (ha) of wetland is doubled from current (2022)[3] extent (biodiversity outcome).
2. By 2050, regional extent (ha) of wetland is returned to the 1997[4] extent (biodiversity outcome).
3. By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome).

In response, the Science Team sought advice to explore the following questions:

1. How these scenarios translate to biodiversity and water quality outcomes for the Region – what does the 2050 vision look like 'on the ground' and in the context of larger biodiversity and water quality goals and objectives?
2. What is the difference between constructed and restored or enhanced[5] wetlands for the purpose of improved water quality outcomes and ecological restoration of wetlands for biodiversity outcomes?
3. What the scenarios mean in terms of implementation, and how does this differ for achieving water quality or biodiversity objectives?
4. What are the implications of the scenarios for areas meeting the definition of a natural wetland in the NPS-FM but which have been induced by surrounding landuse?

1.1. Methods

A literature scan was undertaken to inform the scenario evaluation and response to the project questions. The review was restricted to New Zealand-relevant published literature on constructed wetlands and ecological restoration and enhancement of existing wetlands, with an emphasis on material published in the last 20 years. The literature was further confined to that relating to wetlands constructed for the purposes of treatment (nutrient attenuation[6]) of diffuse agricultural runoff and therefore publications relating to treatment of point-source discharges or stormwater in urban or industrial catchments were excluded.

This scan of the literature informed the evaluation of the policy scenarios (**section 2**) and the responses to the questions Horizons was seeking advice on (**section 3**). A set of criteria were developed in discussion with Horizons' project team to determine the extent to which the three scenarios aligned with current policy directions and desired outcomes for water quality and indigenous biodiversity, as well implications for implementation. In addition to the

[3] As there has not been an update to wetland extent data (Horizons pers. com.) 'current (2022)' extent is taken as the extent (7065 ha) published in 2007 to support the development of the One Plan (Maseyk 2007).

[4] Regional wetland extent data was not able to be obtained for 1996, but regional extent of freshwater wetlands at 1997 (8537 ha) was available (Denyer & Peters 2020) and assumed to be accurate for 1996.

[5] This question, as posed by Horizons, related only to restored wetlands. We have revised this question slightly to reference restoration' and 'enhancement' as we do not used the terms 'interchangeably (see Section 1.2).

[6] The permanent loss or temporary storage of nutrients, sediment, or microbes during the transport process between where they are generated (i.e., in the paddock) and where they impact on water quality (i.e., a downstream water body such as a lake).' (McKergow et al. 2007).

literature review, the wider context and policy direction within National Policy Statements[7] and the One Plan was taken into consideration in this evaluation.

1.2. Definitions

It is not uncommon for terminology associated with the protecting, constructing, restoring, or enhancing of areas of wetland habitat to be used interchangeably. This is understandable as the actions and motivations behind the concepts can overlap. However, vague, inconsistent, or interchangeable usage of terms can create confusion and be especially problematic in the context of interpreting, implementing, or reporting on policy directions. It is therefore useful to draw a distinction between constructed wetlands, restoration of wetlands, and enhancement of wetlands.

A scan of several regional plans[8] reveals that the terms 'restoration', enhancement', 'constructed wetland' or 'created wetland' are used but definitions are not provided within these documents. The NPS-FM goes so far as to explicitly exclude 'a deliberately constructed wetland'[9] from the definition of a natural inland wetland but does not further define the term.

Constructed wetlands are recognised in the literature as artificial wetlands designed to utilise natural ecological process[10] to mimic the filtering functions of natural wetlands, typically targeting nitrogen and sediment (see for e.g., Tanner & Kloosterman 1997; McKergow et al. 2007; Hamill 2010; Tanner et al. 2010). While they may include indigenous species and have similar components as 'natural' (non-constructed) wetlands, constructed wetlands are distinguishable from naturally occurring (even if degraded or modified) wetlands.

The acts of restoration and enhancement can be differentiated on the basis on the former seeks to re-instate (restore, return) lost or heavily degraded habitat or ecosystems to a former natural indigenous-dominated state, while the latter seeks to manipulate existing habitat to improve its condition and function. Thus, the act of enhancement can be targeted at either indigenous or exotic habitats and landscapes. This is also reflected in the NPS–FM definition of restoration which, in linking restoration to natural inland wetlands, precludes the concept of restoration from applying to constructed wetlands:

> *in relation to a natural inland wetland, means active intervention and management, appropriate to the type and location of the wetland, aimed at restoring its ecosystem health, indigenous biodiversity, or hydrological functioning.* [3.21(1)]

Therefore, we differentiate between constructed, restored, and enhanced wetlands as follows:

Constructed wetlands refer to artificial wetlands designed to mimic filtering functions for the purposes of nutrient management. Constructed wetlands may be subject to ongoing manipulation and maintenance to maintain performance.

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7 The National Policy Statement for Freshwater Management 2020 Amendment 1 (NPS-FM) as it applies to the definition of natural inland wetlands, and mapping and monitoring of wetlands and the 2022 Exposure Draft National Policy Statement on Indigenous Biodiversity (NPS-IB) as it applies to restoration goals for wetlands.

8 Including Horizons One Plan, the Auckland Unitary Plan, Bay of Plenty Natural Resources Plan, Southland Water and Land Plan, Waikato Regional Plan.

9 Subclause 3.21 (1) NPS-FM.

10 That is, the hydrological, biological, and physiochemical processes involving wetland vegetation, soils, water, and associated microbial assemblages that occur in natural wetlands to remove, store, and absorb a significant portion of the nutrient load in the receiving waters.

Wetland restoration refers to the manipulation of hydrological or biological characteristics of a former, or heavily degraded, area of naturally occurring wetland habitat for the purposes of recreating indigenous wetland habitat that is representative of type, structure, and composition naturally occurring in the Manawatū-Whanganui Region.

Wetland enhancement refers to conservation management actions undertaken within existing naturally occurring wetland habitat for the purposes of improving the state of the wetland, including structure, composition, and quality, natural diversity, and dominance of indigenous components.

For clarity, constructed wetlands are used in the context of water quality outcomes, while wetland restoration and enhancement are used in the context of advancing indigenous biodiversity outcomes, noting that in some cases both restoration and enhancement actions and interventions will occur concurrently, at the same space in the landscape. Some maintenance activities undertaken within constructed wetlands will be similar to enhancement actions implemented in existing wetlands (e.g., control of pest plant species). However, the type of wetland within which the similar actions may occur remains distinguishable.

We recommend that definitions (especially for constructed wetlands) are included in policy documents and clear distinction is drawn between constructed wetlands and existing or restored natural wetlands in implementing provisions of the One Plan and reporting against policy targets.

2. EVALUATION OF PROPOSED POLICY SCENARIOS

2.1. Introduction

The ecosystem services and associated benefits derived from wetland ecosystems is well known (e.g., Clarkson et al. 2013), including ability to remove sediments and pollutants from water passing through them. These ecological processes translate to provision of ecosystem services and cultural, environmental, social, and economic benefits; and ultimately human wellbeing; through the improvement of water quality (and many other services and associated benefits). However, the drastic loss of wetland habitat in New Zealand (10.08% of former wetland remaining nationally (Dymond et al. 2021) and ~3% of former wetland extent remaining in the Manawatū-Whanganui Region (Maseyk 2007; Ausseil et al. 2008; Denyer & Peters 2020) has stripped and almost completely removed this ecological function from our landscapes.

As natural wetlands have been largely removed from the landscape (or functionally reduced), replacement wetlands need to be constructed. The construction of wetlands provides the opportunity to optimise filtering and attenuation processes that occur naturally in wetland ecosystems as dispersion, flow paths, water depths, residence times and vegetation characteristics can all be manipulated within constructed wetlands to optimise attenuation processes (McKergow et al. 2007).

The national policy requirement reflects the obvious imperative to enhance and restore wetland habitat. Regionally, the drastic decline of wetland habitat in the Manawatū-Whanganui Region and associated loss of cultural, ecological, indigenous biodiversity, and economic values and interruption to and loss of associated provision of ecosystem services has long been known. Horizons initiated an ambitious, non-regulatory wetland enhancement programme in the early 2000s which aimed to bring ten of the Top 100 wetlands under active management per year. The Top 100 wetland programme was rolled into the One Plan (which recognises threatened indigenous biodiversity as one of the 'Big Four' regional issues) as an ongoing non-regulatory method, alongside a comprehensive regulatory framework for the protection of wetlands, to deliver on the indigenous biodiversity objectives and policies[11]. At the time (the One Plan became operative in 2014), the indigenous biodiversity provisions in the One Plan (with the regional council being the lead agency for indigenous biodiversity for the Region) was a national first. However, implementation of the Top 100 wetland programme has not lived up to the programme's own aspirations – after nearly two decades only 21 wetlands have been brought under active management (pers. com. HRC). Regionally, policy performance and outcome monitoring targeted at wetlands is scant at best (Maseyk & Burns 2022) and this has limited the ability to comprehensively evaluate whether this intervention and investment has been well placed, or how long it can be expected to take for that programme (at current settings) to meaningfully contribute to halting and then reversing the trends of decline.

In response to the evident natural resource management and conservation imperative to enhance and restore wetland habitat, and in face of growing expectation and pressure from the wider community, Horizons' policy team proposed the three policy scenarios for further exploration[12]. It is understood that these scenarios, if adopted by Council, would serve as objectives in the One Plan with associated methods of delivery.

The formulation of such objectives and associated implementation needs careful consideration and planning to ensure the programme is designed in a manner that the sought after outcomes will be achieved on-the-ground, and that public funding is spent judiciously to bring about required changes that would not have happened anyway.

To further understand how the policy scenarios translate to biodiversity and water quality outcomes for the Region, an evaluation of the three policy scenarios was undertaken as set out below.

2.2. Underpinning assumptions

The justification for the metrics and targets within the policy scenarios was not provided, and the assumptions underpinning the targets were also not obvious. In the absence of explicit statements, we have assumed the following assumptions have been applied when developing the policy scenarios:

- Wetland habitat, and its fundamental components (e.g., wetland soils, hydrological regimes, wetland vegetation composition, presence of surface water etc.) can be created, manipulated, or enhanced to increase area of wetland habitat.
- There is a direct positive relationship between size of habitat and the quality of that habitat and/or intactness of ecological processes; therefore, increasing regional wetland extent is desirable.
- Size (measured as either extent in hectares, or proportion (%) of the contributing catchment) is an appropriate proxy for other measures of wetland quality and/or function and provision of ecosystem services.
- The increase in wetland cover under the water quality scenario is achieved via constructed wetlands[13] for the purposes of nutrient management and designed to maximise this function.
- The two biodiversity-focused scenarios are alternative options – that is, they would not both be adopted.

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11 A non-complying activity status applies to any activities that have adverse effects on wetland habitats identified to be a 'rare' or 'threatened' habitat and meeting other criteria set out in Schedule F of the One Plan.

12 Pers. com. HRC staff.

13 See definition, section 1.2.

- The biodiversity-focused scenarios and the water-quality focused scenario are independent of each other, describing separate actions and outcomes – that is, they do not contribute to each other.

Considering the above we make the following observations:

- The assumption that wetland habitat can be created and enhanced is supported in the literature and in practice. Indeed, the manageable attributes[14] of natural capital stocks are the critical intervention point to target management actions for purposes of influencing change in ecological processes and the provision of ecosystem services (Figure 1).
- However, enhancing natural capital stocks for the provision of ecosystem services is not merely a function of size, but rather a consideration of the quality, quantity, and spatial configuration of wetland natural capital stocks, which are in turn influenced by other natural capital stocks and environmental and social pressures and drivers[15] sustained over time. Further, the concept of ecological integrity[16] is also broader than extent (Lee & Allen 2011; Bellingham et al. 2016, 2021). We also note that there is no theoretical basis that validates the assumed surrogacy between area and the different elements of habitat condition.
- Representation of the Region's original wetland ecosystem pattern requires the full range of wetland types known from the Manawatū-Whanganui to targeted for protection and enhancement (see for example Leathwick et al. *under review*). Using 'wetland extent' as a measure does not differentiate between wetland type, such that extent of one (or some) wetland types may be increased at the expense of others.
- There are key differences between created and natural wetlands, which are likely to have ecological and conservation implications – not all wetlands are equal.

14 Those attributes that are amenable to manipulation (via management actions) and can be managed at farm or catchment scales.

15 For example, environmental drivers include climate, landform, geology etc, and environmental pressures include natural hazards, invasive species; social drivers and pressures include land use, farming practice, technology, public policy, individual decision-making, climate change (Maseyk et al. 2017).

16 The New Zealand Environmental Reporting Act 2015 defines ecological integrity as *'the full potential of indigenous biotic and abiotic features and natural processes, functioning in sustainable communities, habitats, and landscapes.'* Ecological integrity describes a generalised ecological state but not any particular past state and is a more inclusive definition of an ideal ecological state than 'natural' as the concept recognises humans as part of the system (McGlone et al. 2020). Ecological integrity is fundamentally connected to indigenous biodiversity, ecosystem extent, resilience, and adaptability and restoration priorities.

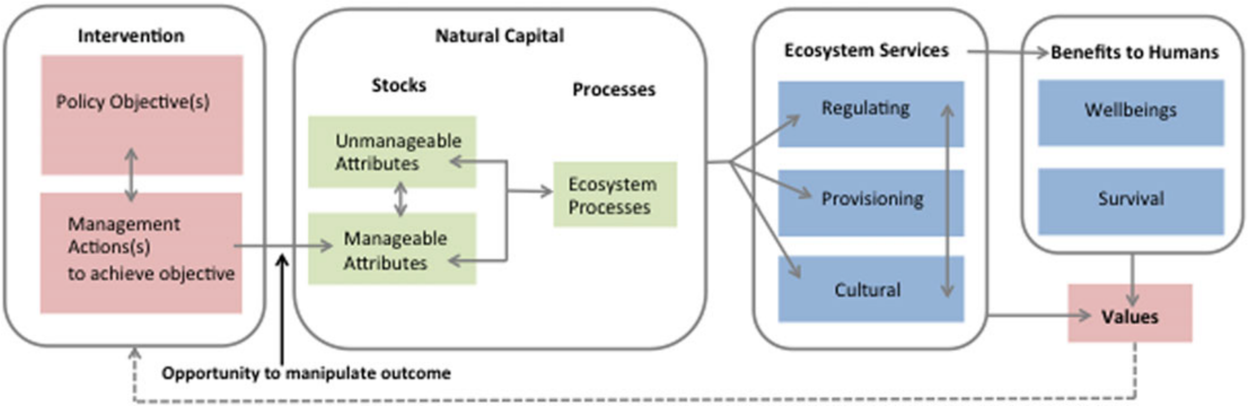

Figure 1: Conceptual relationship between policy and management interventions, natural capital stocks, and provision of ecosystem services, showing opportunity to influence the provision of ecosystem services by targeting manageable attributes of natural capital stocks. Additional drivers (e.g., environmental, and sociopolitical) will also be exerting influence. Other forms of capital (e.g., social, human, and built) will also act upon natural capital to bring about ecosystem services provision, although we note these forms of capital are implicitly captured within management actions and cannot operate in the absence of natural capital. *Source:* Maseyk et al. 2017.

2.3. Results

Evaluation of each of the three policy scenarios was undertaken using the following framework:

	To what extent are:
Framing	Are inherent assumptions appropriate for the statement outcome? Is the right action and elements of wetland habitat targeted? Are the timeframes appropriate?
Strategic direction	Is there potential for the scenario to detract from other policy directions? Will the scenario create tension with other policy direction for wetland habitat?
Policy direction	Does the scenario align with the NPS-FM? Does the scenario align with the One Plan?
Implementation	Is the scenario specific, measurable, achievable, relevant, and timebound (SMART)? Is there an obvious pathway for implementation? Does the scenario allow enough flexibility to allow for new implementation methods/tools to be used? Can implementation be aligned with current wetland programmes?

Due to the similarities in the two policy scenarios targeted at biodiversity outcomes (the only difference being the quantum of the target), we have evaluated these two scenarios together (Table 1). The results for the evaluation of the policy scenario targeted at water quality outcomes is shown in Table 2.

Table 1: Evaluation of the two policy scenarios targeted at biodiversity outcomes. ^Assumptions underpinning the scenarios have been assumed (see section 2.2).

Scenario 1: *By 2050, regional extent (ha) of wetland is doubled from current (2022) extent (biodiversity outcome)* **Scenario 2**: *By 2050, regional extent (ha) of wetland is returned to the 1997 extent (biodiversity outcome)*		
Criteria		**Evaluation**
Framing	Are inherent assumptions^ appropriate for the stated outcome?	Scenarios 1 and 2 rely on the assumption that an increase in area directly relates to an increase in indigenous biodiversity. representation. Relying solely on an increase in extent (ha) to improve indigenous biodiversity is limited. The NPS-FM identifies ecosystem health[17] as a compulsory value, and a target for restoration. However, a 'healthy' ecosystem may not necessarily be indigenous dominated. Therefore, in the context of indigenous biodiversity outcomes, a policy scenario that encapsulates the concept of ecological integrity[18] (which is broader than, but includes extent) would make more ecological sense and capture the concept of ecosystem health (be functioning well), and in addition would align with the national biodiversity monitoring framework being developed by the regional council Biodiversity Working Group and the 2022 Exposure Draft of the National Policy Statement for Indigenous Biodiversity. Regional-scale targeted outcome objectives will be required alongside a revised scenario.

17 Ecosystem health describes the fundamental physical and biological state of an ecosystem in relation to the provision of ecosystem services and incorporates aspects of mauri (McGlone et al. 2020).

18 Defined in the Exposure Draft of the NPS-IB as '*the extent to which an ecosystem is able to support and maintain its (a) composition (being its natural diversity of indigenous species, habitats and communities), and (b) structure (being its biotic and abiotic physical features), and (c) functions (being its ecological and physical processes)*'. Ecological integrity is fundamentally connected to indigenous biodiversity, ecosystem extent, resilience, and adaptability and restoration priorities. A targeted outcome objective of ecological integrity includes indigenous dominance, species occupancy, and environmental representation (Lee & Allen 2011; Bellingham et al. 2016, 2021)

Scenario 1: *By 2050, regional extent (ha) of wetland is doubled from current (2022) extent (biodiversity outcome)* **Scenario 2**: *By 2050, regional extent (ha) of wetland is returned to the 1997 extent (biodiversity outcome)*		
Criteria		Evaluation
	Is the right action targeted?	The inherent action within both scenario 1 & 2 is the creation of wetland habitat. Habitat creation will be required to reverse the trajectory of decline. However, an emphasis on extent alone risks overlooking (or disincentivising) opportunities to improve condition and function of existing wetlands, and/or designing new wetlands to expediate increase in regional extent rather than to create wetland habitat that contributes to ecological integrity, for example the proliferation of wetland habitat that is relatively easier and cheaper to create (such as harakeke swamp) and in places that do not require less palatable land use trade-offs over wetland types that are harder and more expensive to create or in areas where they are less desirable. The creation of new habitat should not be prioritised at the expense of enhancing and protecting existing wetland habitat.
	Are time frames appropriate?	Both scenarios have a time frame of ~25 years (a generation). Under either scenario the regional extent of wetland habitat would still be <10% of former cover. Longer-term visions can be useful however, given the vulnerable state of wetland habitat in the Region, short and medium targets should also be included in support of any long-term policy vision.
Strategic direction	Is there potential for the scenario to detract from other policy directions?	Both scenarios are positive in terms of resulting in an increase in indigenous presence in the landscape however, the broader objective within the One Plan (maintain *indigenous biodiversity,* including enhancement where required) and the directions of the NPS-FM require more than increase in extent.

Scenario 1: *By 2050, regional extent (ha) of wetland is doubled from current (2022) extent (biodiversity outcome)* Scenario 2: *By 2050, regional extent (ha) of wetland is returned to the 1997 extent (biodiversity outcome)*		
Criteria		**Evaluation**
		The two scenarios have a strong potential to favour the creation of areas of wetland habitat that are relatively easier and cheaper to create; and those that appeal aesthetically to landowners (e.g., harakeke swamps, areas of open water).
	Will the scenario create tension with other policy direction for wetland habitat?	It is assumed that Scenarios 1 and 2 are either / or options, but there is potential tension between Scenarios 1 and 2, and Scenario 3 (see Table 2). See also comments above.
Policy direction	Does the scenario align with the NPS-FM?	Aligns with, but does not (on its own) fully provide for, sub-clause 3.22(4), or Policy 6 NPS-FM,
	Does the scenario align with the One Plan?	Yes, although not entirely as the One Plan includes a broader objective for indigenous biodiversity (including wetlands).
Implementation	Is the scenario specific, measurable, achievable, relevant, and timebound (SMART)?	*Specific:* To a very limited extent in that the end goal is specified, but not what needs to be taken to achieve it. Further, the scenarios generically refer to 'wetland'. However, this non-specificity fails to recognise the different types of wetland habitat that naturally occur in the Region, all of which need to be included to ensure environmental representation. *Measurable:* Extent (ha) is generally measurable, although some wetland types and smaller areas of wetland habitat (e.g., seeps) are considerably harder to detect remotely. *Achievable:* In theory yes, although the quantum of new wetland habitat required is not inconsiderable (see Appendix 1, Table A1.1) and will require considerable resourcing. Reflecting on the delivery of

Scenario 1: *By 2050, regional extent (ha) of wetland is doubled from current (2022) extent (biodiversity outcome)* **Scenario 2**: *By 2050, regional extent (ha) of wetland is returned to the 1997 extent (biodiversity outcome)*		
Criteria		**Evaluation**
		Horizons' current non-regulatory wetland programme, these scenarios are unlike to be achieved on a voluntary, opportunistic basis but instead will require a focused, prioritised approach. The feasibility of achieving these scenarios is somewhat unclear without an understanding of what methods are being considered to work towards the outcomes (e.g., regulatory protection of existing wetlands; regulatory requirement for wetland restoration, any use of offset policies to deliver gains in wetland habitat, partnership models etc.)
		Relevant: Yes. Wetland protection and enhancement is a regional and national priority. *Timebound:* End date is specified (see above comments on time frames).
	Is there an obvious pathway for implementation?	Associated objectives, aims, methods of delivery, and implementation plans have not yet been developed but will be essential. Developing an implementation plan for these scenarios will require cross-policy consideration and integration across programmes (e.g., farm planning processes, offsetting policies, catchment management).
	Does the scenario allow enough flexibility to allow for new implementation methods/tools to be used?	Yes, in that the two scenarios do not dictate implementation methods, restoration techniques, or tools to create wetland habitat.
	Can implementation be aligned with current wetland programmes?	From an operations perspective, implementation of these scenarios would logically be an extension of the current wetland programme but would require considerably more effort and resourcing.

Scenario 1: *By 2050, regional extent (ha) of wetland is doubled from current (2022) extent (biodiversity outcome)* **Scenario 2**: *By 2050, regional extent (ha) of wetland is returned to the 1997 extent (biodiversity outcome)*		
Criteria		**Evaluation**
		In addition, substantial background support work will be required. For example, integration with regional conservation planning and prioritisation to identify suitable areas for wetland creation and which wetland types to prioritise and incentivise the creation of.
	Are there obvious barriers to implementation and are these resolvable?	Creation of wetland habitat can be difficult, expensive, requires a long-term commitment to maintain, and requires expertise and resources unlikely to be available to many landowners. This requires an associated long-term commitment to resourcing policy implementation (including monitoring and reporting). Tensions associated with land use trade-offs will be inevitable. The most obvious and effective places to create wetland habitat are in the areas where land has previously been converted from wetland habitat (often at some cost). Resolving these tensions will be challenging and will need a multi-pronged approach including greater understanding and communication of the value of wetland habitat to the farm system, and appropriate incentives and disincentives to drive necessary actions. The shift in land use and long-term resourcing commitment is likely to be politically challenging also.

Table 2: Evaluation of the policy scenario targeted at water quality outcomes. ^Assumptions underpinning the scenarios have been assumed (see section 2.2).

Scenario 3: *By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome)*		
Criteria		**Evaluation**
Framing	Are inherent assumptions appropriate for the stated outcome?	Performance of nutrient processes within wetlands increases as relative area of a wetland (proportion of the contributing catchment) increases, although there are diminishing returns. The target in this scenario (5%) is supported by the literature[19] on constructed wetlands. However, the effectiveness of constructed wetlands is not just a function of size but also their design and maintenance.
	Is the right action targeted?	This scenario relies on a proxy – use of constructed wetlands as a nutrient management tool to achieve water quality outcomes; and conflates (one) means with the ends. Constructed wetlands are only one attenuation tool and there maybe others that would be as or more effective at improving water quality in a catchment[20]. It would be more appropriate to have policy vision that described the *outcome* being sought (in terms of water quality), supported by objectives and methods of delivery that encourage the use of constructed wetlands (in situations where they are the best option for nutrient management on-farm), in line with specific standards (including the required extent in relation to the contributing catchment), and alongside necessary measures to control emissions at source.

19 McKergow et al. (2007) conclude that to achieve 50–60% nitrate and TN removal, constructed wetlands will need to cover 2–3% of the contributing catchment. Smaller wetlands covering 1% of the contributing catchment will generally remove ~30% of nitrogen; whereas wetlands covering 5% of the contributing catchment have the potential to achieve removal of 70% or more of nitrogen (McKergow et al. 2007); although treatment performance will vary year to year.

20 This is 'horses for courses' and determining which tool is the most appropriate requires on-farm assessment, including dominant runoff generation areas and flowpaths. Using the wrong or least effective attenuation tool will undermine efforts to improve water quality (McKergow & Tanner 2011).

Scenario 3: *By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome)*		
Criteria		**Evaluation**
		Source control is generally more effective as attenuation tools (such as constructed wetlands) can be difficult and expensive to design, construct, and maintain (McKergow et al. 2007).
	Are timeframes appropriate?	Noting the above comments regarding the limitations in relying solely on constructed wetlands to achieve water outcome objectives, the timeframe inherent in the scenario is ~25 years, or another generation to achieve the outcomes. Longer-term visions can be useful however, given the degraded state of water quality in the Region, short and medium targets and identification of priority catchments should also be included in support of any long-term policy vision.
Strategic direction	Is there potential for the scenario to detract from other policy directions?	Yes, creating constructed wetlands can potentially detract from indigenous biodiversity outcomes and reporting against the two (indigenous biodiversity and water quality) outcomes should be kept separate (see also Section 3).
	Will the scenario create tension with other policy direction for wetland habitat?	Constructed wetland to intercept nutrients and buffer natural wetland could be way to manage risk of degradation of natural wetlands from nutrient loads, creating a potential synergy between the proposed policy visions (see also comments above). Unless comprising entirely exotic vegetation, constructed wetlands designed as an attenuation tool for nutrient management purposes would be captured by Schedule F of the One Plan (as currently worded) and therefore subject to the policies and rules associated with wetlands (as Rare or Threatened habitat). This would be an inappropriate policy response for constructed wetlands.
Policy direction	Does the scenario align with the NPS-FM?	Yes (and notwithstanding the focus on the method and not the outcome inherent in this scenario), in terms of contributing to

Scenario 3: *By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome)*		
Criteria		**Evaluation**
		achieving water quality directions within the NPS-FM, but not necessarily in terms of promoting the restoration of natural inland wetlands (sub-clause 3.22(4) NPS-FM) in that only nutrient management functioning of wetland is targeted within this scenario. However, the scenario does not directly link to the objectives or policies of the NPS-FM.
	Does the scenario align with the One Plan?	Indirectly (and notwithstanding the focus on the method and not the outcome inherent in this scenario), in that the scenario encapsulates one method of nutrient management which will be required to achieve the broader One Plan objectives for water quality. However, the scenario does not directly link to these water quality objectives.
Implementation	Is the scenario specific, measurable, achievable, relevant, and timebound (SMART)?	*Specific:* To a very limited extent in that the end goal is specified, but not what needs to be taken to achieve it. *Measurable:* Extent (ha) is generally measurable. It is also conceivable that the farm planning process will provide the mechanism by which to implement the use of constructed wetlands, and this creates the opportunity for monitoring and reporting on outcomes. *Achievable:* In theory the construction of wetlands is achievable, although it will require substantial resourcing and assistance to landowners (many of whom will not have the necessary expertise) and a concerted and coordinated effort to reach the 5% of contributing catchment area under agricultural use. So, while achievable it is likely an unrealistic scenario.

Scenario 3: *By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome)*		
Criteria		**Evaluation**
		Critically, constructed wetlands are just one tool for nutrient management, and the desired outcomes (improved water quality) will require other actions to occur, particularly source control.
		Relevant: Improving water quality is a regional and national priority. However, the use of constructed wetlands as a proxy to achieve this may be less relevant in many situations. Thus, the desired outcome is relevant, but the focus on constructed wetlands is limiting. *Timebound:* End date is specified (see above comments on time frames).
	Is there an obvious pathway for implementation?	Requires further specifications to ensure that constructed wetlands are fit for purpose and maximise attenuation. For example, best practice guidance on the design, construction, and maintenance requirements of constructed wetlands (e.g., Klossterman 1997; Tanner et al. 2010) and treatment performance criteria (e.g., Hamill 2010). From an operations perspective, implementation of this scenario would logically be an extension of the current farm planning process but would require considerably more effort and resourcing.
	Does the scenario allow enough flexibility to allow for new implementation methods/tools to be used?	Yes, in that the scenario does not dictate implementation methods or techniques to construct wetlands. However, the scenario is also restrictive in that it confines options to just one attenuation tool (constructed wetlands).
	Can implementation be aligned with current wetland programmes?	Using constructed wetlands for nutrient management is an entirely different focus than protection and enhancing wetland habitat for

Scenario 3: *By 2050, wetland landcover covers 5% of the contributing catchment area within areas under agricultural landuse (water quality outcome)*		
Criteria		**Evaluation**
		purpose of improving indigenous biodiversity and conservation outcomes. The two programmes should not be conflated.
	Are there obvious barriers to implementation and are these resolvable?	Yes. The construction of wetlands is not straight forward and there is inherent variability in effectiveness and cost (Uuemaa et al. 2018). Implementing this scenario will require substantial and sustained investment and availability of expertise, and background investigation. To use wetlands as an attenuation tool requires detailed assessment of potential sites (at farm and catchment scales) for site suitability and ease of interception of dominant flowpaths. A considerable barrier will be the availability of land (and/or willingness to convert land use) needed to maximise efficiency (size, shape, location). Constructed wetlands require regular maintenance, including the periodic checking of inlets and outlets; checking structural integrity; weeds; gates and fences (Tanner et al. 2022).

3. POTENTIAL IMPLICATIONS OF THE PROPOSED POLICY SCENARIOS

We further evaluate the proposed policy scenarios by directly responding to the Science Team's questions. The responses set out below are informed by the literature scan and provide further context for the evaluation set out above (section 2). We note there is some overlap between the questions and have attempted to limit repetition in responding to them. Therefore, this section should be read as a whole. Additional information on the effectiveness of constructed wetlands is provided in Appendix 2.

1. How do the policy scenarios translate to biodiversity and water quality outcomes for the Region, and the broader biodiversity and water quality goals and objectives?

In addressing this broader question, it is useful to first consider the potential of using constructed wetlands as a tool for nutrient management, the co-benefits that may arise, and any trade-offs with indigenous biodiversity outcomes in doing so.

Are constructed wetlands useful for nutrient management on-farm?

Functioning wetlands permanently remove nutrients[21] via denitrification and provide temporary storage of nutrients via plant uptake[22], deposition, adsorption, and mineralisation processes which are re-released back into through flowing waters (McKergow et al. 2007; Tanner et al. 2022). Constructed wetlands have long been recognised and used as a useful tool for point-source wastewater treatment option (Matheson & Sukias 2010; McKergow et al. 2007; Tanner & Kloosterman 1997) and have also been identified as one of the most promising tools available for on-farm and catchment-scale nutrient management (Wright-Stow et al. 2018), as they intercept and treat subsurface flows which may otherwise bypass the natural attenuation processes inherent in shallow groundwaters and riparian zones (Sukias & Tanner 2011). Shallow surface-flow constructed wetlands (comprised of vegetated shallow channels or a series of impoundments) are likely to be the most practical design for cost-effective nutrient treatment in agricultural landscapes. In addition, surface-flow constructed wetlands deal well with variable flow conditions and can cope with greater sediment loads than wetland types reliant on subsurface flow (Tanner et al. 2015b).

Where constructed wetlands are located in the landscape has a fundamental influence on its effectiveness as a nutrient management tool. Uuemaa et al. (2018) cite studies[23] that conclude wetlands should be located as close to the pollution source as possible in the upper catchment at the outlet of the sub-catchment; whereas other studies[24] have shown that wetland attenuate of nitrate-N is better near the bottom of the catchment. McKergow et al. (2007) also recognise that there are alternative locations where constructed wetlands could be located and a range of scales (paddock, farm, catchment) at which they can be used. For example, multiple smaller wetlands placed at the end of tile drains in the upper catchment, or a single, larger wetland located at the bottom of the catchment. One large wetland in bottom of catchment that receives steady flows of diffuse nitrate-rich runoff could be more effective than smaller areas of wetland higher in the catchment which would receive a smaller proportion of the base flow (Uuemaa

21 Nitrogen in runoff from agricultural landscapes is normally present in dissolved nitrate-N form, which is removed via biological processes (microbial denitrification and plant uptake) (Tanner et al. 2022).

22 Unless plant material is removed (e.g., harvested) nutrients will be converted back to soluble, bioavailable forms as plants die (McKergow et al. 2007).

23 Van der Valk AG, Jolly RW 1992. Recommendations for research to develop guidelines for the use of wetlands to control rural nonpoint pollution. Ecological Engineering 1:115–134.
Peterson BJ 2001. Control of nitrogen export from watersheds by headwater streams. Science 292:86–90.

24 Tanner C, Kadlec R 2013. Influence of hydrological regime on wetland attenuation of diffuse agricultural nitrate losses. Ecological Engineering 56:79–88.

et al. 2018). However, this could result in the responsibility for mitigation of runoff in the catchment to be unequally distributed between landowners. Further fundamental influences on effectiveness of constructed wetlands are size relative to the contributing catchment, design and configuration of key components, and environmental variables (e.g., rainfall, climate, amount of nutrient input). Performance is variable between seasons and years and between sites. Therefore, catchment-level considerations will be an important consideration of any implementation plan for constructed wetlands for the purposes of nutrient management.

Phosphorus treatment in constructed wetlands is achieved by sedimentation (settling of P-enriched topsoil), adsorption to wetland sediments and plant uptake. Nitrogen treatment is primarily achieved by denitrification[25] (conversion of nitrate to gaseous nitrogen); although plant uptake, microbial immobilisation and nitrate reduction to ammonium also contribute to a reduction in nitrate removal (Hamill 2010 Matheson & Sukias 2010; Lambie & Hunter 2021). phosphorus retention is expected to be higher when significant proportion of the land loading is in particulate rather than dissolved forms, although desorption and re-release under anaerobic conditions can still occur (McKergow et al. 2007).

However, while wetlands have been shown to be effective for removal of nitrogen, they are less efficient, and more variable, for removal of phosphorus (Hamill 2010; Ballantine & Tanner 2010, 2011; Tanner & Sukias 2011) (see Appendix 2). Wetlands can also be a net source of phosphorus, and removal of dissolved forms of phosphorus[26] tends to require large wetlands, with long residence times (Ballantine & Tanner 2011), and the construction of sediment ponds will be needed to optimise removal of particulate phosphorus (Hamill 2010; Tanner et al. 2022). It is also possible to enhance the nutrient processes within wetlands with the addition of reactive materials[27] to facilitate retention of phosphorus (McKergow et al. 2007; Tanner et al. 2010; Ballantine & Tanner 2011; Tanner & Sukias 2011). This can also improve the cost-effectiveness of using wetlands as a tool for nutrient management by enabling multiple nutrients to be targeted within the same system (McKergow et al. 2007).

When used as a supplementary (alongside source control) or complementary (alongside other attenuation tools), constructed wetlands can be an effective tool for mitigating nutrient losses (runoff) from farm (Goeller et al. 2020; Hamill 2010; Matheson & Sukias 2010; McKergow et al. 2007; Tanner et al 2010; Tanner & Sukias 2011; Uuemaa et al. 2018) and provide additional benefits. However, they are by no means a 'one size fits all' option generating uniform results. Rather, the use of constructed wetlands requires careful assessment of on-farm and catchment-level considerations alongside other attenuation tools and land management practices to reduce nutrient losses in the first instance. Thus, constructed wetlands should ideally be implemented in combination with other land management practices that reduce runoff (e.g., stock exclusion from wetlands and waterways; good fertiliser, grazing, and effluent management practices (Tanner et al. 2010; McKergow et al. 2007)).

Are there additional benefits provided by wetlands constructed primarily for the purposes of water quality?

Additional benefits include ability of constructed wetlands to cope with fluctuating water flows, provide a stock water supply, provide flood attenuation functions, contribute to habitat provisions and indigenous biodiversity, and provide

[25] Particularly in more established constructed wetlands where organic matter has accumulated and carbon is available for denitrification processes.

[26] Although studies concluded that sediment-associated phosphorus retention within natural and constructed wetlands receiving runoff from cropland can be significant (Ballantine & Tanner 2011).

[27] A wide range of materials are suitable for use in farm drainage wetlands to enhance phosphorus removal performance including naturally occurring materials (soils, sands, clays, naturally occurring aggregates (pumice, shale, shell-sand) etc.), processed and modified materials, and waste materials (Ballantine & Tanner 2010).

amenity values (Goeller et al. 2020; McKergow et al. 2007). However, these are secondary considerations and not the primary focus. While there is value in recognising co-benefits arising from constructed wetlands, the contribution of these co-benefits towards regional indigenous biodiversity goals would be difficult to accurately measure without overstating. There are also limitations associated with constructed wetlands, including the potential source of avian *E. coli* and dissolved phosphorus release under anoxia (Goeller et al. 2020).

As with attenuation functions, the provision of co-benefits from constructed wetlands is variable. In particular, where wetlands are located in the landscape will influence the extent to which created (or restored) wetlands will contribute to multiple benefits (Uuemaa et al. 2018). As well as biophysical and environmental variables, farm management practices in the vicinity (e.g., irrigation and drainage) will influence the effectiveness of constructed wetlands (McKergow et al. 2007).

Additional potential advantages from constructed wetlands can arise where they are located in a manner that diverts pollution away from remnant natural wetlands, thus avoiding the risk of degradation of areas of wetland that are a priority for cultural, biodiversity, and conservation outcomes (McKergow et al. 2007).

What are trade-offs between goals for indigenous biodiversity and water quality?

Optimising for particular processes (e.g., nutrient retention) for the purposes of a particular ecosystem service and benefit (e.g., improved water quality) reduces the ability for the constructed wetland to also provide other services or benefits, including contributing to conservation outcomes (Canning et al. 2021).

Inherent tension can be generated between achieving indigenous biodiversity objectives for indigenous wetlands and emphasising the use of constructed wetlands as a tool for nutrient management. This is because the efficiency of constructed wetlands improves where wetlands are constructed using natural landform features such as gullies (Goeller et al. 2022; McKergow et al 2007; Tanner et al. 2015b) and naturally damp areas or other areas also suited for restoration of natural wetland habitat. Where land use pressures occurs, there can also be a temptation to manipulate areas of naturally occurring indigenous wetland for the purposes of maximising nutrient attenuation functions as it does not require land sacrifice, but doing so certainly risks compromising or losing the cultural, biodiversity and conservation values of those wetlands (Tanner et al. 2015b).

It is important not to simplistically conflate the two (indigenous biodiversity and water quality) objectives. Nutrient retention can be delivered by plant species and wetland configurations that differ from those occurring naturally (Hamill 2010). Further, the literature (e.g., Sorrell 2012;) on detrimental impacts of nutrients on wetlands points to a mismatch in thinking that wetlands constructed for the primary purpose of nutrient management can also serve as a solution to the indigenous biodiversity crisis. This is because constructed wetlands designed to optimise nutrient attenuation will not be representative of the full range of wetland types that occur in the Region or representative of natural species compositions, and habitat quality. Constructed wetlands typically (but not always) also favour open water habitat and a limited subset of wetland plant species, and the composition is often heavily influenced by landowner preferences and values rather than ecological restoration principles. Indigenous wetland fauna species can colonise or use habitat provided by constructed wetlands, but the limitations of constructed wetlands to fulfil conservation objectives needs to be understood.

There is some merit in considering the value of restoring very heavily degraded, small remnant natural wetlands (with low ecological and biodiversity values) for the primary purpose of nutrient management and thus improved water quality (Robertson et al. 2016). Compared with the costs of constructing wetlands, there is value in maintaining and enhancing even small naturally occurring wetlands (Tanner et al. 2015a). Further, locating constructed wetlands in areas that already support wetland will increase cost-effectiveness (McKergow et al. 2016). However, such actions should not be conflated with the protection and enhancement of natural wetlands with existing high ecological or cultural values as these values will likely be degraded by the increase of nutrients (Hamill 2010; Robertson et al. 2016; Sorrell 2012).

How do the policy scenarios translate to biodiversity and water quality outcomes for the Region?

The biodiversity-focused policy scenarios are insufficient to adequately describe the required outcomes to improve ecological integrity (including environmental representation) of indigenous wetland in the Region or elevate wetland habitat beyond its current Threatened status (see Appendix 1). Constructed wetlands are not a simple, straight forward, or complete response to addressing the water quality challenges the Region faces. It is counterproductive to form a policy vision for water quality improvement around one (imperfect) attenuation tool.

Key points:

- Constructed wetlands can be a useful attenuation tool for the purposes of nutrient management of agricultural run-off, but it is not a straightforward undertaking.
- The effectiveness of constructed wetlands is dependent on location in the catchment, size relative to the contributing catchment, design and configuration of key components, and environmental variables (e.g., rainfall, climate, amount of nutrient input). Performance is variable between seasons and years and between sites.
- Constructed wetlands are more effective for attenuation of nitrogen than phosphorus.
- The potential for constructed wetlands as a nutrient management tool on-farm is as a supplementary, not an alternative, measure to source control, and when utilised alongside other nutrient management tools.
- While natural wetlands will also provide some level of performance in terms of nutrient attenuation functions, constructed wetlands are designed to optimise this function.
- It is useful to recognise that constructed wetlands will generate some co-benefits beyond the attenuation of nutrients from runoff. However, manipulation of habitat for a primary purpose (nutrient management) will detract from secondary outcomes.
- Using constructed wetlands as a nature-based solution to manage emissions on a farm or catchment-scale should not be conflated with effort necessary to restore indigenous wetland habitat for indigenous biodiversity and conservation outcomes.
- A focus on manipulating wetlands for water quality outcomes risks compromising high ecological or cultural values of existing natural indigenous wetlands, and homogenising wetland habitat (e.g., emphasising open water).

2. Are there differences between constructed and restored or enhanced natural wetlands in relation to freshwater and indigenous biodiversity outcomes?

There is some potential for restored or enhanced wetlands to contribute to the management of diffuse pollution (sediment, nutrient, and faecal contaminant loads[28]) in agricultural runoff (Robertson et al. 2016). For example, natural seepage wetlands at the edge of streams intercept subsurface flow (and some surface runoff), providing

[28] As well contributing to the provision of many other ecological functions and therefore ecosystems services and benefits across cultural, environmental, social, and economic domains (Clarkson et al. 2013).

denitrification, nutrient uptake, deposition, mineralisation, and adsorption attenuation functions and enable the attenuation of sediment and nitrogen, while natural floodplain wetlands intercept flood flows attenuating sediment, phosphorus, and nitrogen via flow attenuation, deposition, nutrient uptake, and denitrification processes (McKergow et al. 2007). Further, natural wetlands that retain connection to stream flow (or could be relatively easily reconnected) have potential to be restored for the purposes of enhancing their nutrient retention functions (McKergow et al. 2007; Hamill 2010; Robertson et al. 2016); and floodplain wetlands can also be constructed (or restored in areas that were previously floodplain) to mimic these natural functions. Even small areas of natural wetlands can retain their attenuation ability and contribute to the reduction of contaminants exported off-farm and into receiving environments (Tanner et al. 2015a).

However, context is everything. The performance of natural wetlands in terms of various processes and functions (and therefore provision of ecosystem services) is influenced by the quality, quantity, and spatial configuration of the natural capital stocks associated with the wetland. Natural habitat (constructed or otherwise) cannot provide the attenuation functions when the ecosystem is overloaded with nutrients. In such situations, the input of excessive nutrients becomes highly problematic as nutrification is a major driver of wetland decline in agricultural landscapes in Aotearoa New Zealand (Sorrell 2012). Further, natural wetlands (like constructed wetlands) will be subject to variation in performance and less effective than wetlands constructed primarily for nutrient management purposes. Hamill et al. (2010) found natural wetlands to be the least effective wetland type for removal of nitrogen, with floating wetlands followed by constructed wetlands to be the most effective. Seepages were considered less effective than constructed wetlands but more effective than natural wetlands for removal of nitrogen but less effective than natural wetlands for removal of phosphorus, while constructed wetlands are more effective than both seepages and natural wetlands (Hamill et al. 2010).

Therefore, there are limitations to the functionality of natural wetlands as attenuation tools because the input of nutrients causes degradation (Sorrell 2012), and a high risk to ecological and cultural values in using natural wetlands for the purposes of nutrient management.

Constructed wetlands can contribute to the provision of habitat and indigenous biodiversity outcomes, but it is important to recognise they are constructed and maintained first and foremost as an attenuation tool and therefore designed to optimise attenuation functions. While constructed wetlands mimic the natural processes and ecological function of natural wetlands, their structure, vegetation assemblages, and pattern of open water is not representative of all wetland types or naturally occurring wetland communities. This is because to optimise nutrient attenuation, constructed wetlands need to adhere to specific design characteristics and management that compromise other cultural, ecological, and biodiversity values of wetlands (Hamill 2010). Thus, wetland constructed or restored for provision of ecosystem services (e.g., nutrient attenuation) can detract from ecological and biodiversity goals (Matzek 2018).

Constructed wetlands (for water quality outcomes) and created or restored wetlands for biodiversity and conservation outcomes should not be seen as interchangeable – they require explicit and distinct policies and implementation plans as well as monitoring and reporting. Although there are important and fundamental differences between constructed wetlands and restored or enhanced wetlands.

Key points:

- Wetlands constructed for purposes of nutrient management and natural wetlands restored for the purposes of indigenous biodiversity outcomes are typically different in structure, composition, and function. They are not interchangeable.

3. What do the scenarios mean in terms of implementation and how does that differ for achieving water quality and indigenous biodiversity outcomes?

The drivers, considerations, design principles, management actions, and maintenance requirements are not the same for constructed wetlands as for the restoration (or enhancement) of wetlands for indigenous biodiversity and conservation outcomes. The public-private benefit split and consideration of duty of care responsibilities also differs between constructed wetlands and restored or enhanced wetlands. Therefore, the two targets cannot be bundled together at the design or implementation level. Rather we suggest the two objectives require differently targeted programmes:

1. A region-wide programme to restore and enhance wetlands for indigenous biodiversity outcomes[29].
2. Active, supported promotion of the use of constructed wetlands as a nutrient management tool (alongside other attenuation tools).

Restoration or enhancement of wetlands for indigenous biodiversity outcomes

Any ambitious goal for wetland indigenous biodiversity outcomes will require a resourcing effort to match and overt statements of how this may be achieved. This would include consideration of how various avenues for resourcing or effort may contribute to, or be integrated with, the wetland enhancement programme, and new ways of doing things to achieve (and then maintain) desired outcomes. Some of which may involve a practice-shift and courageous leadership. For example:

- Hapū and iwi-led wetland restoration and enhancement initiatives.
- Financial contributions (imposed by condition of consent)[30].
- Biodiversity offset or compensation proposals[31], including considering exchange rules that require a proportion of any proposal to be targeted at habitat creation (to increase extent) not simply an exchange of area for condition.

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29 Noting such a programme would also have benefits in terms of enhancement of cultural values and progress towards achieving abundance, contribution to the provision of ecosystem services, and economic benefits.

30 One Plan Policies 19-1–19-3.

31 The One Plan and the NPS-FM provide a consenting pathway for impacts on wetland habitat where effects are managed via the effects management hierarchy, including the use of offsets (to achieve no net loss and preferably a net gain) and compensation to address residual adverse effects. See Maseyk et al. (2022) for further discussion on potential for offsets and compensation to contribute to regional priorities for indigenous biodiversity.

- Partnerships with other agencies and landowners.
- Opportunities for the restoration of public land, including large-scale projects (e.g., floodplain wetlands)[32].

Achieving indigenous biodiversity outcomes on a regional-scale will require systematic spatial planning and prioritisation[33] and adherence to ecological restoration principles to avoid ad-hoc efforts that favour the wetland types that are relatively easier and cheaper to restore and create or are overly influenced by landowner preferences. Any implementation plan for the restoration and enhancement wetlands for indigenous biodiversity outcomes needs to be inseparably linked to regulatory protection of existing wetlands so that further loss of wetland habitat does not occur. Further, restoration and enhancement programmes cannot occur in isolation of consideration of the drivers of decline (and the interplay between them) present in the wider catchment. Particularly disrupted hydrological regimes (due to surrounding landuse) and risks from nutrient losses from farm run-off, but also other surrounding landuse pressures, pest animal presence, and invasive plant species (see for e.g., Sorrell et al. 2012) etc. These issues cannot be ignored when designing site-specific work plans.

In terms of nutrients, nitrogen, and phosphorus, are the two main growth-limiting nutrients for plants and therefore the two main nutrients that will need to be managed in wetland restoration and enhancement projects (Sorrell 2012). Nutrients are an essential element of wetland ecosystems and natural wetlands vary in their nutrient contents. However, the natural attenuation abilities of wetland ecosystems means that once nutrients enter a wetland they tend to stay there, accumulating in the soil, plants, and surface water. Once nutrients are at excessive levels (the threshold of which differs between wetland types and wetland sites), eutrophication occurs[34]. Runoff induced eutrophication is a major driver of degradation[35] of wetlands second only to disturbance to hydrological disturbance (Sorrell 2012). Thus, it is imperative to manage, at both catchment and farm scales, nutrient input into natural wetlands created or restored for the purposes of biodiversity or conservation outcomes. Failure to do will compromise the success of attempts to restore and enhance the ecological value of natural wetlands (Sorrell 2012; Robertson et al. 2016).

32 For example, 721 ha within the publicly managed Moutoa floodway was originally wetland habitat and provides a unique opportunity for large-scale wetland restoration and a re-think of flood management in the lower Manawatū that could have multiple benefits across ecological, indigenous biodiversity, and cultural values. (Peter Taylor pers. com.; Forest & Bird wetland campaign (Koordinates 2022)).

33 Taking into consideration for example, connectivity, adequacy, complementarity, representativeness, irreplaceability, vulnerability, and efficiency (which recognises constraints and competing demands). (See e.g., Knight et al. 2013; Moilanen et al. 2009; Leathwick et al. *In press*.). Regional spatial planning could be done together with (or in parallel) to other indigenous habitats as part of broader regional objectives for indigenous biodiversity.

34 This occurs when the inherent ability of wetlands to filter contaminants and slow flows is exceeded by the volume and velocity of flows into the wetland and the concentration of contaminants, which is typical within intensely farmed catchments. The harvest of plant material to remove excess nutrients from the system can be a key component of wetlands constructed for nutrient management purposes.

35 Excessive nutrient in a wetland typically causes plants to grow taller and denser resulting in loss of plant diversity as tall fast-growing species outcompete other native species. High nutrient levels also favour pest plant species which further reduce plant diversity and transform vegetation communities. Excessive plant growth can also block water flows and increase sedimentation and evapotranspiration which leads to reduced water availability (and loss of aquatic habitat); increase volume of dead litter (high in nitrogen and phosphorus) which releases nutrients into water when decomposed leading to changes in algal communities from slow growing and diverse to communities dominated by problem algae. The process of decomposition of high levels of biomass can cause de-oxygenation and anaerobic conditions (Sorrell 2012).

Constructing wetlands for the purpose of nutrient management

While we caution against constructing a policy vision around a single tool (see Table 2), we note the potential to use constructed wetlands alongside other methods (in particular, source control) for nutrient management, and therefore include some comment on implementation challenges here.

Constructed wetlands are complex systems operating amongst environmental varied landscapes and correspondingly, nutrient attenuation performance is also complex and varied. The cost of construction also varies (Uuemaa et al. 2018). Individual landowners are unlikely to have the skills and knowledge required to design, implement, and maintain a constructed wetland unassisted. If Horizons' was to actively promote the use of constructed wetlands for nutrient management, we highlight the following issues and challenges will need to be considered when designing an implementation plan and anticipating outcomes from the use of constructed wetlands:

- The inherent variability of functionality of wetlands that depends on soils, topography, hydrology (including, rainfall patterns, groundwater levels, drainage), and land ownership (Tanner et al. 2010; Uuemaa et al. 2018).
- The need for an understanding of the hydrology[36] at the catchment-level to be able to optimise the interception of flow pathways (McKergow et al. 2007), and as flow regime is a key factor influencing performance of nitrate-N removal of surface-flow wetlands (Tanner & Kadlec 2013).
- The need for considered on-farm assessment to identify and assess dominant runoff generation areas and flowpaths and determine which attenuation tool is best in the first instance (McKergow et al. 2007).
- Design specifications to ensure adequate wetland area, depth, and length to width ratios[37] are sufficient to provide wetland assimilative area and efficient hydraulic characteristics and conditions suitable for establishment and dense growth of emergent vegetation to optimise the removal of nitrogen and phosphorous (see for e.g., Tanner et al. 2015b).
- The site-specific assessment required for optimising wetland construction (including substrate) for phosphorus removal (Ballentine & Tanner 2010).
- The challenges in incorporating constructed wetlands into modified drainage networks (Tanner et al. 2015).
- The need to fill gaps in understanding regarding performance of constructed wetlands in different landscapes to ensure regulators tool will deliver and landowners can be confident in their investment (Wright-Stow et al. 2018).
- The need to better understand how variation in size, structure, configuration, plant composition, and soil type of constructed wetlands influences the microbial community composition[38], to improve understanding of the contribution of the microbial community to the nutrient attenuation performance of constructed wetlands (Lambie & Hunter 2021).
- The difficulties associating with establishing clear links between field-scale variability in nitrogen export (i.e., hydrological delivery pathways and timing and catchment scale attenuation) (Goeller et al. 2020).

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36 As water is the driving force behind pollutant transfer, providing the energy and the carrier.

37 Length to width ratio and shape of constructed wetlands is important to promote even flow and to reduce excessive flow velocities, short-circuiting of flow or creation of flow dead-zones (Tanner et al. 2010).

38 Microorganisms transform water-borne dissolved nitrogen to gaseous forms and establish biofilms on plant structures, enhancing sedimentation of particulates and are therefore vital for nutrient attenuation performance. Different microbial communities are present in open water and solid compartments of constructed wetlands (Lambie & Hunter 2021).

- The time-lag for constructed wetlands to reach maturity and the year-to-year seasonal differences[39] due to establishment and maturation of constructed wetland[40]; and the implications for reporting on progress towards water quality improvement outcomes.
- The challenge of the necessary land sacrifice to provide the area needed to maximise the ability for a constructed wetlands to attenuate nutrients, noting that the bigger (relative to the contributing catchment) the wetland the better the treatment received (Tanner et al. 2010) with diminishing returns in terms of attenuation performance (Tanner & Kadlec 2013) (See also Appendix 2).
- The high likelihood that sediment-rich flows will be a concern in many catchments in the Manawatū–Whanganui Region, and therefore constructed wetlands will require the instalment of an inlet pond that operates as a sediment trap that can be cleared out periodically. This requires additional space (10% of the surface area of the constructed wetland, Tanner et al. 2010).
- The inequities of land sacrifice that may arise should the best option be a larger wetland at the bottom of the catchment rather than several smaller wetlands scattered throughout the catchment.
- The inherent complexity and challenge in constructing wetlands that requires knowledge and skills that are beyond the farmer (Praat et al. 2015) and the level of resourcing to assist landowners in this endeavour.

In light of the above challenges, we emphasise that the use of constructed wetlands for nutrient management should be considered as one tool within a more comprehensive suite of tools and approaches that accommodate system variability and site-specific conditions and characteristics and not as a focus of a policy vision. This recommendation is supported by Goeller et al. (2020) who conclude that effective management of excessive nitrogen in agricultural landscapes requires the use of multiple, and combined, attenuation tools. Specifically, Goeller et al. (2020; p 2) noted the importance of the following to accommodate system variability and to work within social and productive landscapes:

1. *managing small waterways to elicit effective change in the receiving environment,*
2. *targeting local N export dynamics and underlying hydrological variability from agricultural land to waterways, and*
3. *overcoming factors limiting N attenuation with suites of edge-of-field to waterway-based tools at multiple scales and locations. We also emphasize the need to*
4. *encourage co-development of novel, effective, multiple-tool, multiple-scale waterway N attenuation approaches by scientists, practitioners, and farming communities to overcome the technical and practical challenges to managing N in agricultural landscapes.*

We also note there is considerable New Zealand-specific, practical guidance on the construction, use, and maintenance of constructed wetlands for the purposes of improving water quality (see for example: Tanner & Kloosterman 1997; Tanner et al. 2010; Tanner et al. 2022) that could be incorporated into detailed farm planning processes for farms where the use of constructed wetlands was assessed to be appropriate.

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[39] Including differences in timing and magnitude of runoff events, inter-event duration, and seasonal timing of loadings in relation to microbial denitrification activity and plant growth and senescence (McKergow 2007).

[40] Which influences the availability of organic C substrates for denitrification), plant and microbial assimilation, storage and turnover of nutrients and variability in flow and influent concentration (Tanner & Kadlec 2013; Tanner et al. 2005a; 2005b).

Key points:

- Wetland restoration and enhancement for indigenous biodiversity at the scale required will require the bringing together of multiple opportunities to deliver outcomes and courageous leadership to bring about a change in practice and to ensure indigenous biodiversity outcomes are not undermined by the parallel urgency to address water quality issues.
- The use of constructed wetlands for nutrient management is highly complex and the outcomes variable. They should be considered as one tool, alongside and in combination with, other attenuation tools and as supplement to source control. This has considerable implications for implementation, which needs careful and considered assessment at the farm and catchment-scales, supported by background work to understand the systems at play (e.g., hydrological regimes, pollutant sources, and flowpaths).

5. What are the implications of the scenarios for areas meeting the definition of a natural wetland in the NPS-FM but which have been induced by surrounding landuse?

The NPS-FM defaults to the meaning of wetland as defined in the Resource Management Act 1991 (RMA) where it does not meet the exclusions set out in the NPS-FM. At face value this definition of a natural inland wetland can therefore be tripped by wetland areas induced by land use practices (as well as those induced by natural processes). Examples[41] of wetlands induced by surrounding land use that Horizons' have encountered include:

- Uncapped, overflowing bores which have, over time, created a natural wetland
- Poorly managed stormwater runoff that has formed a wetland.
- Induced wetlands created through forestry practices that cause changes in topography leading to the development of wetland values over time.
- Roads or railway corridors impending drainage (due to bunding) leading to development of wetlands.

We note that in situations such as the overflowing bore and poorly management stormwater, the issue would be rectified with the resolution of the primary issue (by capping of the bore as is required, and correct management of stormwater). As such, situations like these should be viewed as compliance issues relating to the primary issue of concern rather than the creation of wetland habitat that is then subject to the provisions of the NPS–FM (or the One Plan). Further, Schedule F of the One Plan[42] excludes areas of induced wetland that have formed alongside roads or railway corridors. Where confined to ditches, these areas will also generally be constrained in shape, area, and composition and are likely to provide limited opportunities to contribute substantially to regional-scale policy visions for restoration and enhancement of wetland for indigenous biodiversity outcomes.

However, wetlands induced by other land use practices, such as forestry or pastoral farming where changes in topography and landform have altered drainage patterns, may be providing important function(s) and/or support important indigenous biodiversity values. These areas should not be disregarded outright and given the vulnerability of wetland habitat to further loss it is appropriate such areas trip policy provisions. The appropriate management response and potential for enhancement of induced wetlands will be site-specific.

41 Provided by Horizons' staff.

42 Table F.2(b) iv.

There is no direct implication between the proposed policy scenarios and induced wetlands, although induced wetlands (If indigenous biodiversity values are low) on land used for pastoral farming could be targeted for the purpose of nutrient management (by enhancing the attenuation ability).

4. RECOMMENDATIONS

Drawing on the above evaluation and key points we make the following recommendations:

- **Rework** the proposed policy scenarios.
  a. For indigenous biodiversity outcomes the scenario needs to be **broader than just extent** (e.g., be focused on ecological integrity), and provide additional direction so that some wetland types are not unduly favoured over others.
  b. The policy scenario for water quality outcomes requires reframing to focus on the end and the not the means, and which allows for a tailored solution ('right practice, right place') to fit on-farm and catchment variables. Such a scenario can then be supported with objectives and methods of delivery that that encourage the use of constructed wetlands (in situations where they are the best option for nutrient management on-farm), in line with specific standards (including the required extent in relation to the contributing catchment) and which take into consideration equity for landowners and practical and social issues that might prevent constructed wetlands from being located in areas or be of a size that would optimise their ability to and effectiveness at attenuating runoff.
  c. Scenarios for both outcomes need to be supported with interim objectives, and detailed implementation plans that set out methods of delivery and integration across policy streams.
- **Manage expectations of performance of constructed wetlands**. The complexities of design, construction, operation, and maintenance of constructed wetlands suggests the use of constructed wetlands as attenuation tools is not a straightforward, uniform, or singular response to water quality issues. This is reflective of the complexities of natural systems and interactions of biotic and abiotic elements and processes. It follows that a tool designed to mimic natural processes would also be subject to similar complexities. Further, the area of land required (in the right place) for constructed wetlands is not insubstantial (see Appendix 2). Given the resourcing (land, financial[43], skills, knowledge, time) associated with constructed wetlands, the expectations for performance need to be carefully managed.
- **Utilise whole farm planning processes** to determine appropriate attenuation tools (including constructed wetlands) and detail site-specific construction and maintenance work plans.
- **Utilise existing guidance documents** for constructed wetlands (including appropriateness of use, design (size, shape, depth, length to width ratio, location), composition, appropriate plant selection, maintenance requirements, maintain fish passage etc.) and support further research to reduce knowledge gaps.
- **Redesign and resource the wetland enhancement programme** (for indigenous biodiversity outcomes). Reflecting on Horizons' current voluntary initiatives to monitor and enhance and restore wetland habitat, it is evident that any future initiatives cannot simply be a continuation or extension of these programmes.

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43 Costs were estimated (in 2017) to be $100,000–$200,000 / ha for construction (where excavation is required, which it typically is) and implementation costs of about $2000–$5000/ha of farmed catchment (Tanner et al. 2017).

Future policy initiatives need to be supported with clearly stated objectives and a well-designed implementation plan that:

a. Is underpinned by systematic spatial planning and restoration principles.

b. Addresses landscape-scale pressures that can undermine success of restoration and enhancement efforts, including source control of nutrient losses in the first instance.

c. Includes the suite of avenues to achieve outcomes, including overt statements on the contribution from other policy initiatives and requirements (e.g., biodiversity offsets and compensation, financial contributions, regulatory protection of wetland habitat etc.).

d. Incorporates iwi and hapū-led wetland restoration and enhancement initiatives.

e. Includes a research plan to fill knowledge-gaps and explore opportunities for large-scale restoration of wetland habitat (e.g., across floodplains or riparian wetlands inside stop banks).

f. Includes outcome monitoring and reporting against objectives (as part of the wider indigenous biodiversity monitoring and reporting programme), and policy effectiveness evaluation to determine the extent to which the implementation of the policies is driving any observed change.

- **Recognise the resourcing required will be ongoing.** Greater resourcing is needed in terms of both strategic planning, programme oversight, and delivery of works on the ground. It is preferable to do less better than more badly, which risks creating long-term liabilities and future costs. There is an inherent tension here with the scale of restoration and enhancement needed to address the biodiversity (and climate change) crisis and the implications for resourcing that goes with the enormity of the job. Undertaking a systematic spatial planning exercise at the outset can assist to prioritising funding. The construction and maintenance of constructed wetlands for nutrient management would logically be an on-farm cost. However, other aspects of implementing constructed wetlands (and other attenuation tools) for nutrient management would benefit from regional investment (e.g., the catchment-level information required) for ultimately a public good. For both indigenous biodiversity and water quality outcomes, careful consideration of public funding is required to ensure basic duty of care or consenting obligations are not subsided, the sought after outcomes are achieved on-the-ground, and public funding is spent judiciously.
- **Monitor and report on outcomes separately**. Potential co-benefits arising from constructed wetlands should be acknowledged, but not counted towards targets for the restoration and enhancement of wetland habitat for indigenous biodiversity outcomes. Where co-benefits for indigenous biodiversity outcomes can be demonstrated these outcomes could be reported alongside (for the appropriate metrics).
- **Make amendments to the One Plan** to provide for constructed wetlands as follows:
  - Include a permitted activity rule for the construction of wetlands for the purposes of nutrient management with associated conditions and standards relating to location, design specifications, (etc.), and which clearly prevent the modification of an existing wetland that meets the definitions and criteria set out in Schedule F.
  - Include wetlands constructed for nutrient management purposes in Table F.2(b), Schedule F of the One Plan, so they are not considered Threatened habitat for the purposes of the indigenous biodiversity provisions of the One Plan.

REFERENCES

Ausseil A-GE, Dymond JR, Shepherd JD 2007. Rapid mapping and prioritisation of wetland sites in the Manawatu-Wanganui Region, New Zealand. Environmental Management 39:316–325.

Ballantine DJ, Tanner CC 2010. Substrate and filter materials to enhance phosphorus removal in constructed wetlands treating diffuse farm runoff: A review. New Zealand Journal of Agricultural Research 53(1):71–95.

Ballantine DJ, Tanner CC 2011. How can we enhance phosphorus removal in constructed wetlands. In Currie LD, Christensen CL (Eds), Adding to the knowledge base for the Nutrient Manager. Occasional Report No. 24. Palmerston North, New Zealand: Fertiliser and Lime Research Centre, Massey University.

Bellingham PJ, Overton JMcC, Thomson FJ, MacLeod CJ, Holdaway RJ, Wiser SK, Brown M, Gormley AM, Collins D, Latham DM, Bishop C, Rutledge DT, Innes JG, Warburton B 2016. Standardised terrestrial biodiversity indicators for use by regional councils. Landcare Research contract report LC2109 prepared for Regional Councils' Biodiversity Monitoring Working Group.

Bellingham P, Richardson S, Burge O, Wiser S, Fitzgerald N, Clarkson B, Collins K. 2021 Standardised methods to report changes in the ecological integrity of sites managed by regional councils. Envirolink Grant: 2039-HBRC252 report prepared by Manaaki Whenua – Landcare Research and Collins Consulting for Hawke's Bay Regional Council.

Canning AD, Jarvis D, Costanza R, Hasan S, Smart JCR, Finisdore J, Lovelock CE, Greenhalgh S, Marr HM, Beck MW, Gillies CL, Waltham NJ 2021. One Earth 4:937–950.

Clarkson BR, Ausseil A-GE, Gerbeaux P 2013. Wetland ecosystem services. In Dymond J (Ed), Ecosystem services in New Zealand – conditions and trends. Lincoln, New Zealand: Manaaki Whenua Press.

Denyer K, Peters M 2020. The root causes of wetland loss in New Zealand: An analysis of public policies and processes. National Wetland Trust.

Dymond JR, Sabetizade M, Newsome PF, Harmsworth GR, Ausseil A-G 2021. Revised extent of wetlands in New Zealand. New Zealand Journal of Ecology 45(2):3444.

Kooridinates 2022. Areas of historic wetland that are now grass but still in public ownership (Sept. 2022). https://koordinates.com/layer/113000-areas-of-historic-wetland-that-are-now-grass-but-still-in-public-ownership-sept-2022

Goeller BC, Febria CM, McKergow LA, Harding JS, Matheson FE, Tanner CC, McIntosh AR 2020. Combining tools from edge-of-field to in-stream to attenuate reactive nitrogen along small agricultural waterways. Water 12:12020383.

Goeller BC, Tanner CC, McKergow LA, Vincent AG, Hicks AS, James TI, de Monchy PJM, Murphy D, Phipps RJ 2022. Quantifying and demonstrating constructed wetland contaminant attenuation from mixed agricultural runoff. In Christensen CL, Horne DJ, Singh R (Eds), Adaptive Strategies for Future Farming. Occasional Report No. 34. Palmerston North, New Zealand: Farmed Landscapes Research Centre, Massey University.

Hamill K 2010. Wetland feasibility for nutrient reduction to Lake Rotorua. Opus Report Reference: 2-34068.00 prepared for Bay of Plenty Regional Council.

Kadlec RH, Tanner CC, Hally VM, Gibbs MM 2005. Nitrogen spiralling in subsurface-flow constructed wetlands: Implications for treatment response. Ecological Engineering 25:365–381.

Knight AT, Rodrigues ASL, Strange N, Tew T, Wilson KA 2013. Designing effective solutions to conservation planning problems. In MacDonald DW, Willis KJ (Eds), Key Topics in Conservation Biology 2 pp 362–383. John Wiley & Sons Ltd.

Lambie SM, Hunter DWF 2021. Microbial composition in different physical compartments of six constructed wetland systems in New Zealand. Ecological Engineering 166:106238.

Leathwick JR, Whitehead AL, Singers N, Daly E *Under review*. Establishing an evidence-based framework for the conservation of New Zealand's terrestrial ecosystems. New Zealand Journal of Ecology.

Lee WG, Allen RB 2011. Recommended monitoring framework for regional councils assessing biodiversity outcomes in terrestrial ecosystems. Landcare Research contract report LC144 prepared for Regional Councils' Biodiversity Monitoring Working Group.

Maseyk F 2007. Past and current indigenous vegetation cover and the justification for the protection of terrestrial biodiversity within the Manawatu-Wanganui Region: Technical report to support policy development. Horizons Regional Council Report No: 2007/EXT/790.

Maseyk FJF, Mackay AD, Possingham HP, Dominati EJ, Buckley YM 2017. Managing natural capital stocks for the provision of ecosystem services. Conservation Letters 10(2): 211–220.

Maseyk F, Burns E 2022. Requirements for inland wetlands under the National Policy Statement for Freshwater 2020. Technical advice to support implementation. The Catalyst Group Contract Report No. 2022/175, prepared for Horizons Regional Council.

Maseyk F. Ussher G, Christensen M 2022. Improving outcomes from biodiversity offsetting and compensation. Challenges and opportunities for the use of strategic mechanisms. Contract Report No. 2022/173 prepared for the Regional Council Biodiversity Working Group. The Catalyst Group, RMA Ecology, and Natural Resources Law.

Matheson FE, Sukias JP 2010. Nitrate removal processes in a constructed wetland treating drainage from dairy pasture. Ecological Engineering 36:1260–1265.

Matzek V 2018. Turning delivery of ecosystem services into a deliverable of ecosystem restoration. Restoration Ecology 26(6):1013–1016.

McGlone MS, McNutt K, Richardson SJ, Bellingham PJ, Wright EF 2020. Biodiversity monitoring, ecological integrity, and the design of the New Zealand Biodiversity Assessment Framework. New Zealand Journal of Ecology 44(2):3411.

McKergow LA, Tanner CC, Monaghan RM, Anderson G 2007. Stocktake of diffuse pollution attenuation tools for New Zealand pastoral farming systems. NIWA Client Report: HAM2007-161 prepared for Pastoral 21 Research Consortium.

McKergow L 2015a. FOCUS: Maximising the effectiveness of farm plans. NIWA Client Report No. HAM2015-026 prepared for Envirolink.

McKergow L, Faulkner T, Steward A, Parkes R, Ihaka S, Elliott S, Mackay A, Freeman M, Longhurst B 2015b. FOCUS – Farm plans, outcomes, catchment priorities and users. In Currie LD, Burkitt LL (Eds), Moving farm systems to improved attenuation. Occasional Report No. 28. Palmerston North, New Zealand: Fertiliser and Lime Research Centre, Massey University.

Moilanen A, Wilson KA, Possingham H (Eds) 2009. Spatial Conservation Prioritization. Quantitative Methods and Computational Tools. Oxford, UK: Oxford University Press.

Ndebele T, Forgie V 2017. Estimating the economic benefits of a wetland restoration programme in New Zealand: A contingent valuation approach. Economic Analysis and Policy 55:75–89.

Praat J, Sukias J, Faulkner T, Bichan A 2015. Benefits and costs of a constructed wetland on a Wairarapa dairy farm. Journal of New Zealand Grasslands 77:173–176.

Robertson HA, Clarkson BR, Campbell DI, Tanner CC 2016. Wetland biodiversity, ecosystem processes and management. In Jellyman PG, Davie TJA, Pearson CP, Harding JS (Eds), Advances in New Zealand Freshwater Science Chapter 12. New Zealand Freshwater Sciences Society and New Zealand Hydrological Society.

Sukias J, Tanner CC 2021. Surface flow constructed wetlands as a drainage management tool – Long term performance. In Currie LD, Christensen CL (Eds), Adding to the knowledge base for the Nutrient Manager. Occasional Report No. 24. Palmerston North, New Zealand: Fertiliser and Lime Research Centre, Massey University.

Sorrell B 2012. Nutrients. In Peters M, Clarkson B (Eds), Wetland Restoration. A Handbook for New Zealand Freshwater Systems Chapter 8. Lincoln, New Zealand: Manaaki Whenua Press. First published 2010.

Tanner CC, Kloosterman VC 1997. Guidelines for constructed wetland treatment of farm dairy wastewaters in New Zealand. NIWA Science and Technology Series No. 48.

Tanner CC, Nguyen ML, Sukias JPS 2005a. Constructed wetland attenuation of nitrogen exported in subsurface drainage from irrigated and rain-fed pastures. Water Science & Technology 51(9):55–61.

Tanner CC, Nguyen ML, Sukias JPS 2005b. Nutrient removal by a constructed wetland treating subsurface drainage from grazed dairy pasture. Agriculture, Ecosystems and Environment 105:145–162.

Tanner CC, Sukias JPS, Yates CR 2010. New Zealand guidelines for constructed wetland treatment of tile drainage. NIWA Information Series No.75.

Tanner CC, Kadlec RH 2013. Influence of hydrological regime on wetland attenuation of diffuse agricultural nitrate losses. Ecological Engineering 56:79–88.

Tanner CC, Sukias J, Burger DF 2015a. Realising the value of remnant farm wetlands as attenuation assets. Moving Farm Systems to Improved Nutrient Attenuation. 28th Annual Fertiliser and Lime Research Centre Workshop, 10–12 February, Massey University, Palmerston North. Fertiliser and Lime Research Centre.

Tanner CC, Sukias J, de Winton M, Larned S, Sutherland D, Hughes A 2015b. Wetland nutrient attenuation assessment or inflows to Te Waihora / Lake Ellesmere. NIWA Client Report No. HAM2015-040 prepared for Whakaora Te Waihora.

Tanner CC, Depree CV, Sukias JPS, Wright-Stow AE, Burger DF, Goeller BC 2022. Wetland practitioners guide: Wetland design and performance estimates. NIWA and DairyNZ.

Uuemaa E, Hughes AO, Tanner CC 2018. Identifying feasible locations for wetland creation or restoration in catchments by suitability modelling using Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM). Water 10:464.

Wilcock RJ, Müller K, van Assema GB, Bellingham MA, Ovenden R 2011. Benefits of wetlands in farming landscapes – The Toenepi Catchment. In Currie LD, Christensen CL (Eds), Adding to the knowledge base for the Nutrient Manager. Occasional Report No. 24. Palmerston North, New Zealand: Fertiliser and Lime Research Centre, Massey University.

Wright-Stow AE, Tanner C, Matheson F, Stephens T, Quinn J, Burger D, Young J 2018. Accelerating uptake of constructed wetlands and riparian buffers by quantifying attenuation performance: A proposed national investigation. In Currie LD, Christensen CL (Eds), Farm Environmental Planning – Science, policy, and practice. Occasional Report No. 31. Palmerston North, New Zealand: Fertilizer and Lime Research Centre.

APPENDIX 1: Extent of change in wetland cover required to meet various policy scenarios

The change in area (ha) of wetland needed to meet various scenarios, and the yearly rate of change has been calculated (Table A1.1). Scenarios 1 and 2 are Horizons' proposed policy scenarios; scenarios A–C depict alternative targets (10%, 20%, 30% of former (pre-human) extent remaining) for the purposes of comparison. Under scenarios 1, 2, A, & B, wetland habitat would remain 'Threatened'[44] in accordance with the One Plan. Only scenario C (if achieved) would shift the classification of wetland habitat up a category from 'Threatened' to 'At Risk' under the One Plan.

Table A1.1 Required change in wetland extent (hectares) under various scenarios. Former extent is taken as 232,254 ha, current extent is taken as 7064 ha (Maseyk 2007). Annual rate of change required is calculated over a 25-year period.

Scenario (By 2050–)		Extent if scenario achieved (ha)	Change from current extent (ha)	Rate of change required (Ha /year)
1	Regional extent (ha) of wetland is doubled from current (2022) extent	14,129	7065	283
2	Regional extent (ha) of wetland is returned to the 1997 extent	8537	1473	59
A	Regional extent (ha) of wetland is 10% of former extent	16,161	9096	364
B	Regional extent (ha) of wetland is 20% of former extent	39,386	32,322	1293
C	Regional extent (ha) of wetland is 30% of former extent	62,612	55,547	2222

44 Those naturally uncommon wetland habitat types would remain as 'Rare' under Schedule F of the One Plan under any of the scenarios.

APPENDIX 2: Summary of effectiveness of constructed wetlands

The literature on constructed wetlands identifies a myriad of factors influencing the effectiveness of constructed wetlands to attenuate nutrients. A brief summary of some key factors is provided below:

- **Size**. Size (relative to the contributing catchment) is an important factor of effectiveness. Tanner et al. (2010) concluded, based on multi-year data in the North Island, that wetland area that is 5% of the area of the catchment draining into the wetland can remove 38–68% (average of 53%) of annual nitrate-N. However, finding the space for this in the appropriate location to intercept flow paths will be challenging on many farms.

Catchment area (ha)	Required area for constructed wetland
20	1 ha (10,000 m^2)
10	0.5 ha (5000 m^2)
1	0.05 ha (500 m2)

  However, there are diminishing returns from wetlands in terms of attenuation performance. Tanner & Kadlec (2013) concluded that an increase of wetland size from 1% to 2% of the contributing catchment improved performance by ~75%, but an increase in wetland area from 2% to 4% of the contributing catchment only improved performance by a further ~43%.

- **Location**. The performance of constructed wetlands will depend on local environmental factors (flow regime and amount of nutrient input, rainfall, climate) and will vary between seasons and years.

- **Temperature and residence times**. Constructed wetlands work best when residence times are long and water temperatures are high; and performance is poorer in cold, wet, winter periods (McKergow et al. 2007; Tanner et al. 2010; Tanner et al. 2015b; Tanner et al. 2022).

- **Type of wetland**. Seepage wetlands are more efficient at nitrogen removal than other surface wetlands systems as there is increased contact between water and organic soil particles (and therefore increased denitrification) as the spring water emerges through the wetland soils (Hamill 2010). However, seepages tend to be small and scattered and this will limit the ability of seepages to removal mass concentrations of nitrates and will also be hard to monitor and manage (Hamill 2010).

- **Nitrogen spiralling** (repeated uptake and release along a flow path). In flowing systems, repeated cycling of nutrients and other solutes become spatially displaced by downstream transport. The tightness of length of the spiral and nature of each cycle influence retentiveness and processing rate (Kadlec et al. 2005). Nitrogen spiralling in constructed wetlands increases the nitrogen residence time relative to the hydraulic retention time (Kadlec et al. 2005), making performance levels of these wetlands relatively resilient to short-term fluctuations of nutrient inputs (Robertson et al. 2016).

- **Runoff**. Runoff from different sources (surface drains, subsurface drains, overland flow, stream flow) and different landscapes have different characteristics therefore performance of constructed wetlands will depend on wetlands being constructed with detailed consideration of local information. Therefore, there is a need for further long-term studies to better understand long-term performance and influence of event-to-event and year-to-year variations (Tanner et al. 2005).

Performance estimates for constructed wetlands (assuming that wetlands are constructed in accordance with best practice recommendations) are provided in Table A2.1 and Figures A2.1–A2.3. A summary of a sample of New Zealand studies describing effectiveness of wetlands as attenuation tools is provided in Table A2.2.

Table A2.1: Summary of performance estimates (over the long-term) for constructed wetlands receiving surface drainage and runoff within catchment rainfall of 800–1600 mm/year. ^Not applicable to areas with clay soils (>35% clay content). Expected performance assumes wetlands are constructed in accordance with the recommendations set out in the DairyNZ NIWA Wetland Practitioner Guide, and stated caveats are taken into account. Data from Tanner et al. 2022.

Contaminant	Expected performance (contaminant reduction) / relative area	
	Relative wetland area 1% of catchment area	Relative wetland area 5% of catchment area
Sediment (total suspended solids)^	50%	90%
Nitrogen (total nitrogen) – warm climate zones	25%	50%
Nitrogen (total nitrogen) – cool climate zones	20%	40%
Phosphorous (total phosphorus)^	25%	50%

As the relative area of constructed wetland increases from 1% of the contributing catchment to 5% the expected long-term average of total suspended sediment increases from 50 to 90% (Figure A2.1; Tanner et al. 2022).

For nitrogen, the performance of constructed wetlands is influenced by temperature. In warm climate zones, the expected removal of total nitrogen via constructed wetlands increases from 25 to 50% as relative area of constructed wetlands increases from 1 to 5% of the contributing catchment; whereas in cool climate zones the expected removal increases from 20% to 40% (Figure A2.2; Tanner et al. 2022).

Estimates derived for warm (average annual temperature >12°C) and cool (average annual temperature 8–12°C) climatic zones with catchment rainfall of 800–1600 mm/year.

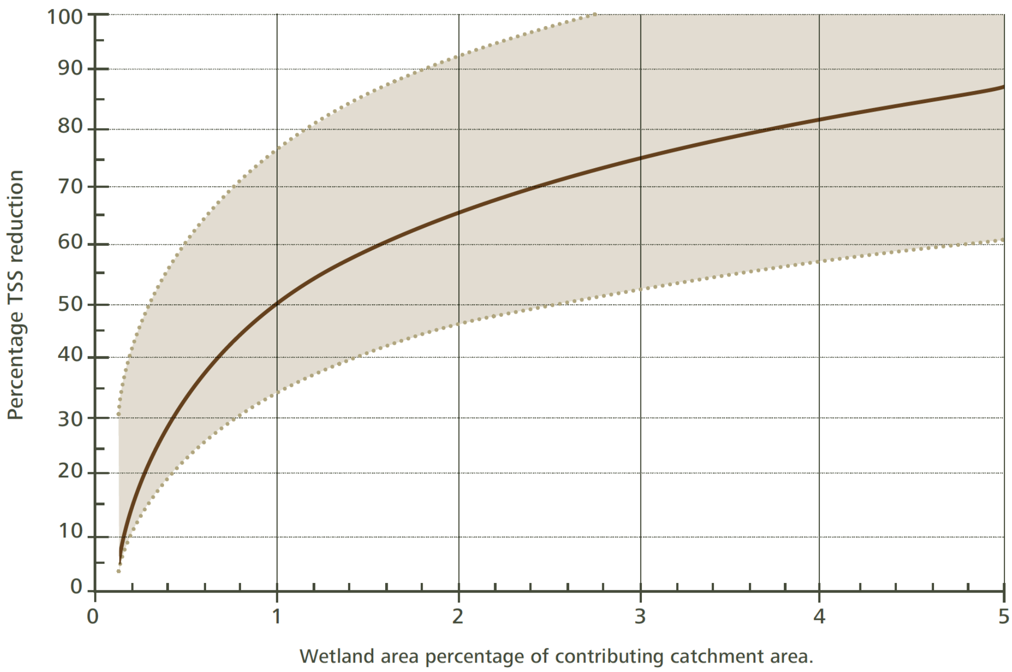

Figure A2.1: Performance estimates (long-term median annual reduction) for total suspended solids removal by constructed wetlands. Solid line shows expected median. Shaded areas show the inter-annual and inter-site range of expected performance. Performance estimates are not applicable to areas with clay soils (>35% clay content). *Source*: DairyNZ and NIWA Wetland Practitioner Guide (Tanner et al. 2022).

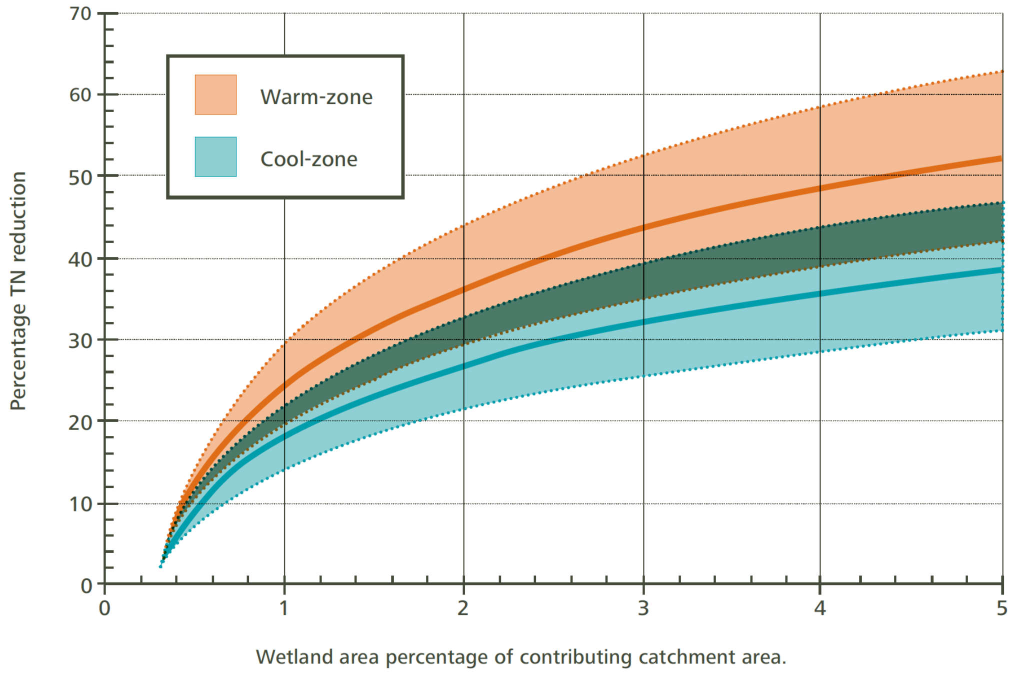

Figure A2.2: Performance estimates (long-term median annual reduction) of total nitrogen reduction by constructed wetlands. Solid lines show expected medians for each zone; shaded areas show inter-annual and inter-site range. Warm-zone = average annual temperature >12°C; Cool-zone = average annual temperature 8–12°C. *Source*: DairyNZ and NIWA Wetland Practitioner Guide (Tanner et al. 2022).

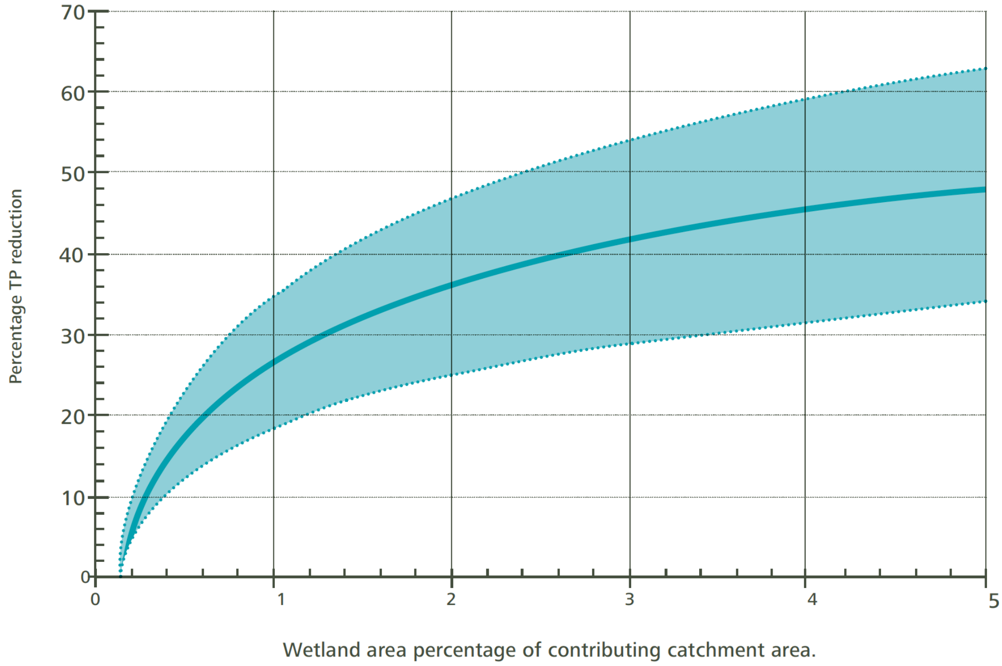

Figure A2.3: Performance estimates (long-term median annual reduction) of total phosphorus reduction by constructed wetlands. Solid lines show expected median; shaded areas show inter-annual and inter-site range. Performance estimates are not applicable to areas with clay soils (>35% clay content) or constructed wetlands whose main source of flow is subsurface drainage containing predominantly dissolved forms of phosphorous. *Source*: DairyNZ and NIWA Wetland Practitioner Guide (Tanner et al. 2022).

Table A2.2: Summary of a sample of New Zealand studies describing effectiveness of wetlands as attenuation tools. ^Not the primary source of the study / data quoted.

Study location / description	Wetland description	Scale	Reduction / removal rates	Additional comment	Reference
Waituna Catchment	Constructed wetlands located in natural swales and gullies intercepting ~60–90% of surface and subsurface runoff	2–3% of contributing sub-catchment	~30–40% reduction in nitrate-N losses Substantial reduction in suspended solids and particulate P loads	–	Tanner et al. 2015
Short and longer term studies around the North Island	Natural seepage under baseflow conditions	–	>75% removal of nitrate	Removal rates will be less during events, or where channels allow nutrient bypassing of soils	McKergow et al. 2007^
Tracer study of nitrate movement and removal	Seepage wetland	< 350 m2	>90% nitrate removal	In emerging spring water	Hamill 2010^
A six-month study over a period experiencing numerous rainfall events	Seepage wetland	0.2% of catchment area	51% nitrate removal	–	McKergow et al. 2007^
15-month study on a Waikato dairy farm	Natural seepage wetland intercepting surface and subsurface flows	–	70–95% reductions of nitrate-N	Wetland was sometimes source of ammonia-N, dissolved organic N, and particulate N	McKergow et al. 2007^
Input and output experiments	Natural seepage wetland	–	5–15 mg/N/m^2/d	Localised 'hot spots' within wetlands where denitrification rates are very high	McKergow et al. 2007^
Whatawhata Over a six-month period including storm events	Seepage wetland	0.2% of catchment area	54% TN retention (inflow up to 20 g/d) 26% TP retention (inflow up to 2 g/d) 1% PP retention 51% NO_3-N retention (inflow up to 30 g/d)	–	McKergow et al. 2007^

Study location / description	Wetland description	Scale	Reduction / removal rates	Additional comment	Reference
Toenepi Catchment (pastoral dairy farming)	Upland seepage area	~1% of catchment area	~95% total P ~95% particulate C 70% particulate N 70% *E. coli*	Very little denitrification occurred due to prevailing oxidising conditions; oxidising conditions	Wilcock et al. 2011
Wairarapa dairy farm demonstration wetland	Wetland constructed within naturally wet area	–	~7% reduction in N loss (from 14 to 13 kg N/ha/yr)	Dissolved reactive phosphate may not necessarily be reduced Counts if *E. coli* increase in wetland outflow	Sukias et al. 2015
Pastoral dairy farm, North Island	Surface flow constructed wetland receiving highly pulsed drainage flows	~1% of catchment	21–79% for TN (mass removal efficiency) 82–>99% large pulses of Org-N 11–49% seasonal loads NO_3-N	Released more TP and DRP than received Can be net sources of NH_4-N, DRP, and TP Removal efficiency of TN associated with annual variations of N export from the catchment	Tanner et al. 2005b
Pastoral dairy farm, Toenepi, Waikato	Subsurface flow constructed wetland planted with raupo	0.66% of catchment	11–52% Annual nitrate-N loads 7–63% TN	Phosphorus removal was generally poor from both; in some years P export was twice what was received Ammonium and organic-N often increased	Sukias & Tanner 2011
Pastoral dairy farm, Bog Burn, Southland		1.6% of catchment	24–59% Annual nitrate-N loads 26–42% TN		
Estimated efficiency (based on NZ data)	Natural seepage wetlands in riparian zones and toe-slope of hills	Low density 1% of catchment low perimeter/area ratio (0.35) 100 m^2/ha High density	60% reduction of sediment overland flow load entering wetland 50–75% N reduction 10% reduction in particulate P from surface runoff*		McKergow et al. 2007

Study location / description	Wetland description	Scale	Reduction / removal rates	Additional comment	Reference
		5% of catchment high perimeter/area ratio (0.75) 500 m^2/ha		*No specific New Zealand or relevant overseas data for phosphorus reduction, expected figures are provided Detailed assumptions provided in reference	
	Constructed wetlands in landscape features that intercept surface and shallow subsurface runoff (e.g., depressions, gullies, wet areas)	Low density 1% of catchment 100 m^2/ha	~60% + reduction of annual load in surface runoff 30% N reduction (annual range 10–40%) 50–60% reduction in particulate P from surface runoff *		
		Moderate density 2.5% of catchment 250 m^2/ha	~80% + reduction of annual load in surface runoff 60% N reduction (annual range 40–80%) 60–80% reduction in particulate P from surface runoff*		

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