Cost-effective water quality improvement: a framework for cooperative wetland development

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Abstract

The quality of freshwater in rivers and lakes is a key issue for many New Zealanders. Water quality has declined in some places, and some locations that used to be able to be used for swimming, gathering food or providing ecosystem services are no longer able to be used for those purposes. However, improving water quality can be very expensive with additional flow-on impacts that can affect economic and social wellbeing. Hence there is a need to find solutions that allow for cost-effective water quality improvement.

This research paper looks at one of these solutions; cooperatively developed large constructed wetlands. Wetlands are often described as the kidneys of the landscape due to their ability to efficiently mitigate contaminants that reduce water quality. The idea is simple in theory if not in practice; a group of enterprises in a subcatchment pool their resources together and build a large constructed wetland that mitigates their contaminant losses more cost-effectively than if they each undertook individual mitigations on their own properties.

This research paper assesses the cooperative wetland development solution through the lens of the Institutional Analysis and Development framework and utilises economic theory, Ostrom's principles for successful group private cooperative action, and interview data from on-the-ground water quality stakeholders. A pathway for cooperative wetland development is shown and the challenges and opportunities are highlighted.

It is hoped that this research paper will advance the discussion of cooperatively developing wetlands and the issue of cost-effective water quality improvement in general.

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1 Introduction

Around New Zealand many communities, sectors and government agencies are grappling with how best to achieve desired water quality outcomes. There has been direction from central government, under the National Policy Statement for Freshwater Management 2014 (NPS-FM), for communities to work together to define what level of water quality is desirable or acceptable.

One mitigation that can be highly cost-effective at improving water quality is building large constructed wetlands (Moore, 2008; Kroger, 2008; Dordio, Carvalho, & Pinto, 2008; Doole, Elliot, & McDonald, 2015a; Doole, Elliot, & McDonald, 2015b). Large constructed wetlands can efficiently mitigate contaminants from multiple properties, though the costs of building large wetlands are often more than any one property can afford.

Hence there is a need for a solution that would assist property owners and others to cooperate in order to develop large constructed wetlands that would mitigate contaminants from multiple properties, to meet water quality targets in a cost-effective way.

This research paper has undertaken analysis to determine a pathway that could organise multiple properties in a catchment to cooperatively work together to build and maintain these large constructed wetlands.

The outputs of this research could result in both improvements in water quality and reduced mitigation costs for properties.

1.1 Scope

Whilst water quality is an inherently inter-connected field and any solutions to water quality issues need to sit within an integrated approach, this research paper's scope is limited to looking ways and means to achieving the cooperative development of large wetlands.

This research will focus primarily on the water quality context in the Waikato region of New Zealand, though it is hoped that the outcomes from this research could be useful in other regions and perhaps even further afield.

1.2 Methodology

This research paper begins by outlining the background for the water quality context in New Zealand and the Waikato region in particular. Then economic theory will be utilised to identify factors that would need to be overcome in order to achieve a cooperative and socially optimal solution.

An investigation of Ostrom's (1990) principles for successful cooperative group processes and the Institutional Analysis and Development framework (IAD framework) (Ostrom, Cox, & Schlager, 2014) is undertaken to determine best private cooperative action practice.

Twelve semi-structured interviews with water quality stakeholders have also been conducted, including individuals from local government, farmers, sector organisations, wetland experts and community members. Interviewees were asked to identify what kind of factors and steps would be required to ensure the success of a large constructed wetland development programme. Interviewees talked about how a scheme like this could work in practice and feedback was given on what they thought the barriers and enablers to implementing this kind of scheme would be. The feedback from these interviews has been invaluable for informing the development of this research paper and is integrated throughout.

Using the learnings from the investigation of economic theory, Ostrom's principles, the IAD framework and feedback from interviewees, an analysis has been undertaken that highlights a pathway that could possibly work for organising multiple properties to cooperate in a group environment in order to develop a large constructed wetland.

1.3 Assumptions

Some assumptions that are relevant to this research are outlined below. It is assumed that:

1. The efficacy of wetlands for improving water quality is established and the science on this is taken as a given. A short discourse on the efficacy, cost-effectiveness and uncertainties regarding wetlands is provided in Appendix 1.
2. Potential sub-catchments, with clearly defined boundaries, can been identified that could be suitable for a cooperative wetland project and that at least in some subcatchments the cooperative development of a large constructed wetland is part of the most effective solution for improving water quality for that subcatchment and/or downstream of that subcatchment
3. All individuals and entities are accountable for contaminant losses from their property and enterprises, and therefore a proportion of the water quality issues in their subcatchment. Furthermore, for the purposes of this research paper it is assumed that in the future each enterprise will have individual targets for each of the four main contaminants (nitrogen, phosphorus, sediment and microbes) and that if they don't achieve those targets there are legitimate enforcement options available to ensure that limits are met
4. Proportions of contaminant targets can be measured or estimated to a degree of accuracy that is acceptable for the purposes of monitoring and enforcement. For some contaminants this will be easier than others, i.e. nitrogen can be readily estimated in OVERSEER™. For other contaminants it may be possible over time to measure accurately what is lost on a property scale. However it is assumed that, as a minimum, percentage bands of confidence intervals[1] can be estimated for all main contaminants, from each enterprise in a subcatchment.
5. The regional council will accept the wetland as a legitimate mitigation option and there is an understanding or agreement from the regional council that it will allow the wetland to be used to meet a proportion of water quality targets
6. The community in a particular subcatchment will be able to self-organise and self-determine their cooperative group process (with facilitation and assistance from the council and industry groups if needed). This process needs to be led by the community in which the wetland will sit.

[1]For example, being able to say with 95% confidence that property A is contributing 8-9% of the sediment in this subcatchment.

1.4 Worked example – the Moakurarua subcatchment

Throughout this research paper a worked example will be used to illustrate how particular aspects could look in a real world setting. The Moakurarua subcatchment in the Waikato region will be utilised for these worked example sections and real information, data and aspects of the real life institutional context will be used whenever possible.

2 Background

Good quality water sustains life and communities, supports healthy ecosystems and mahinga kai (food gathering), enables recreation and tourism, is essential for key economic industries and is a taonga and a cultural treasure to Māori (Land and Water Forum, 2010). Some of the key reasons for improving water quality are to maintain healthy ecosystems (including for gathering food) and to enable recreational uses, such as swimming (Healthy Rivers/Wai Ora - Collaborative Stakeholder Group, 2015).

Many contaminants can affect the quality of water. Four of the most important contaminants are Nitrogen, Phosphorus, Sediment and Microbes. High levels of Nitrogen (N) and Phosphorus (P) can result in excessive plant and algae growth which can affect water clarity, more frequent and larger toxic algal blooms and ecosystem health (Ministry for the Environment & Stats NZ , 2017). High levels of sediment affects water clarity (and hence swimmability), can create built up sediment areas and often has other contaminants (mainly P and Microbes) attached to the sediment particles (Department of the Environment, Heritage and Local Government (Ireland), 2010). Some microbes (commonly measured by the proxy microbe *E.coli*) can potentially cause illness if ingested by humans. Hence high levels of microbes affect the swimmability of water bodies (Ministry for the Environment & Stats NZ , 2017) .

2.1 Water quality context

Water quality in New Zealand has been declining in some places, improving in others but tends to be worse in areas where there is significant urban or pastoral land cover (Ministry for the Environment & Stats NZ , 2017). There is a need to address any downward trends in order to restore and protect waterways for future generations.

However improving water quality can be very costly and the potential economic and social costs of large scale water quality improvement are significant (Doole, Elliot, & McDonald, 2015b). There is a need to find a cost effective and enduring solution for improving water quality.

2.1.1 National level context

Many of the recent reforms in the New Zealand's national water quality and quantity policy have been influenced by the Land and Water Forum (LAWF) process. LAWF consists of a group of stakeholders from organisations that represent key interests in and users of water (Land and Water Forum, 2012a). They have produced four reports on water (Land and Water Forum, 2010; Land and Water Forum, 2012a; Land and Water Forum, 2012b; Land and Water Forum, 2015). These reports detail a plethora of recommendations for implementing a system that would improve management of water. The government has taken some of these recommendations on board and developed a key piece of policy for water quality, the National Policy Statement for Freshwater Management.

The National Policy Statement for Freshwater Management (NPS-FM) was first introduced in 2011 with the current version being from 2014 with amendments in 2017 (NPS-FM, 2017). The NPS-FM (2017) sets the national direction for the management of land and water and includes some bottom lines for water quality attributes. The national bottom lines relate to limits for attributes such as total nitrogen and *e.coli* that relate to the values trying to be achieved, such as ecosystem health and human health for recreation (NPS-FM, 2017). Under the NPS-FM (2017) the water quality of all freshwater bodies must be either maintained or improved and any freshwater bodies that fall under the bottom lines must be improved to at least this level.

2.1.2 Waikato level context

In the Waikato region there is a document called Te Ture Whaimana o Te Awa o Waikato or The Vision and Strategy for the Waikato River (Waikato River Authority, 2013). The Vision and Strategy is the primary direction-setting document in the Waikato river catchment and has the highest legal standing (above the NPS-FM). Local agencies are required to 'give effect' to the Vision and Strategy by restoring and protecting water quality (Waikato River Authority, 2017).

This document had its genesis in the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010, and included all the remaining Waikato River Iwi once their settlement legislation was enacted (Ngāti Tūwharetoa, Raukawa and Te Arawa River Iwi Waikato River Act 2010; Nga Wai o Maniapoto (Waipa River) Act 2012). The Vision and Strategy sets out objectives and strategies for the Waikato River (as well as all of its tributaries including the Waipa River), with the ultimate measure being "that the Waikato River will be safe for people to swim in and take food from over its entire length" (Waikato River Authority, 2013, p. 2). In practice the Vision and Strategy has led to the co-governance and co-management of the Waikato river catchment between the Waikato Regional Council and the five Waikato River Iwi; Ngāti Tūwharetoa, Te Arawa River Iwi, Raukawa, Ngāti Maniapoto and Waikato-Tainui (Waikato Regional Council, 2014).

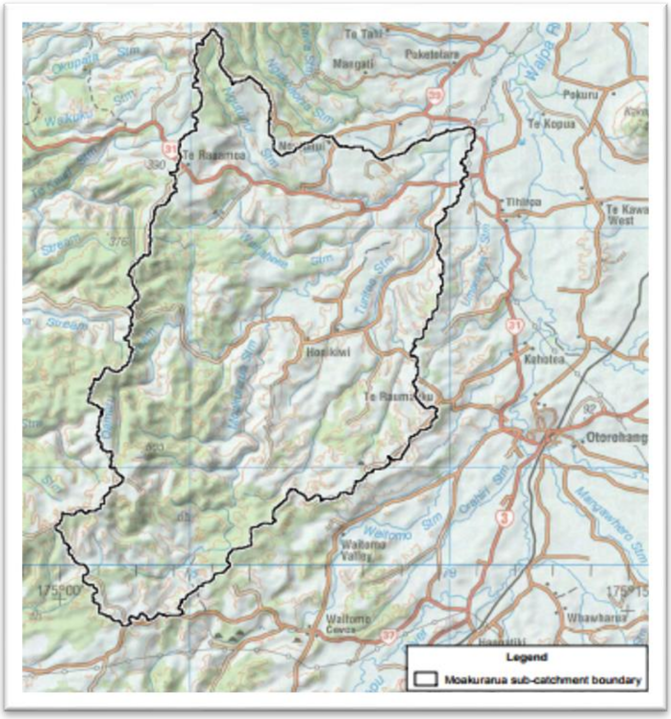
In order to give effect to the Vision and Strategy and the NPS-FM the Waikato Regional Council (WRC) embarked upon a plan change process, called Healthy Rivers/Wai Ora, to the Waikato Regional Plan. This process was overseen by co-management and co-governance committees.

The main decision making group in the Healthy Rivers/Wai Ora process was a 25-person strong Collaborative Stakeholder Group (CSG), consisting of stakeholders from sectors with interests in water quality and representatives from local communities (Waikato Regional Council, 2014). The CSG was tasked with intensively reviewing the technical and community material to form recommendations (Waikato Regional Council, 2014). These recommendations (see Healthy Rivers/Wai Ora - Collaborative Stakeholder Group, 2016) formed what became known as Plan Change 1.

Plan Change 1 sets out objectives and methods as well as water quality limits and targets. Plan Change 1 is currently under the RMA schedule 1 process with hearings scheduled to occur on submissions to the plan change in 2018 (Proposed Waikato Regional Plan Change 1, 2017).

There are a number of water quality limits and targets in Plan Change 1 for both the short term (i.e. the next ten years) and the long term (i.e. the next 80 years), over ten attributes and 74 subcatchments (Waikato Regional Council, 2016).

The Moakurarua subcatchment (Healthy Rivers/Wai Ora unique ID no. 42) is located on the western border of the Waipa Freshwater Management Unit (FMU). The town of Otorohanga is to the east and Waitomo Caves are to the south.



Map 1: Moakurarua sub-catchment (map courtesy of Waikato Regional Council)

There are several streams in the subcatchment the biggest of which is the Moakurarua Stream, which connects to the main stem of the Waipa River.

The area of the subcatchment is around 20,630 ha, which is roughly 7% of the Waipa FMU area. However, only around 12,889 ha of the subcatchment is currently 'productive land', i.e. land that is not forestry, urban areas or areas such as the streams themselves.

The long term, 80-year timeframe, targets for the four main contaminants for this subcatchment are equivalent to reductions of around 35% for Nitrogen, 40% for Phosphorus, 55% for Microbes and 62% for Sediment.

2.1.3 Current policy approaches

There are some current approaches to wetland development for improving water quality in the Waikato region that are worth noting.

Predominantly wetland development for improving water quality occurs at an individual farm scale with a mix of private and public funding. There are several funding sources for projects such as this, such as funding from the Waikato River Authority. However, funding is always limited and those who know about these funding sources tend to be better financially and environmentally performing land owners anyway.

There are also not-for-profit wetland advocacy groups, such as the National Wetland Trust, that provide information, promote the benefits of wetlands and assist with demonstration sites. This voluntary, information and advocacy approach is important at spreading the word regarding the effectiveness of wetlands. However, as interview participants noted, the establishment cost of setting up a wetland is still the biggest barrier to uptake.

Under the Healthy Rivers/Wai Ora proposed plan change 1 there are provisions for 'edge of field' mitigations that will help to enable and encourage the uptake of large constructed wetlands. In particular, Policy 9 (d) states:

> "This approach includes: Allowing, where multiple farming enterprises contribute to a mitigation, for the resultant reduction in diffuse discharges to be apportioned to each enterprise in accordance with their respective contribution to the mitigation and their respective responsibility for the ongoing management of the mitigation." (Waikato Regional Council, 2016)

This is an important policy for a cooperatively developed wetland solution as it allows for multiple enterprises to use a sub-catchment scale mitigation as a means to meet there individual water quality targets.

Also implementation method 3.11.4.5 (b) states that:

> "Sub-catchment scale planning will: Utilise public funds to support edge of field mitigations where those mitigations provide significant public benefit" (Waikato Regional Council, 2016)

This method highlights that where there is public benefit, public funds are appropriate to be spent on ensuring that the benefits occur.

However none of the current or proposed approaches would go far enough to achieve the very large uptake required of wetlands as suggested by the Doole, Elliot and McDonald reports (2015a; 2015b) and others such as Daigneault et al (2017).

It should also be noted that, as interview participants highlighted, wetlands are not going to fix the problems on their own; they are not a panacea. A multi-faceted approach will be required with a mix of sub catchment level actions, like constructed wetlands, and individual actions on properties, such as stream bank fencing or a change in production system.

3 Concepts

3.1 Economic Rationale for Intervention – Positive Externalities

Positive externalities occur when someone indirectly benefits from the actions of another individual or enterprise. This can involve monetary and/or non-monetary benefits (Roach, Harris, & Codur, 2015).

The additional benefits caused by the positive externality can be illustrated on a graph. The costs of the externality can be added to the Marginal Benefit (Demand) curve to create a Social Marginal Benefit curve, as can be seen below:

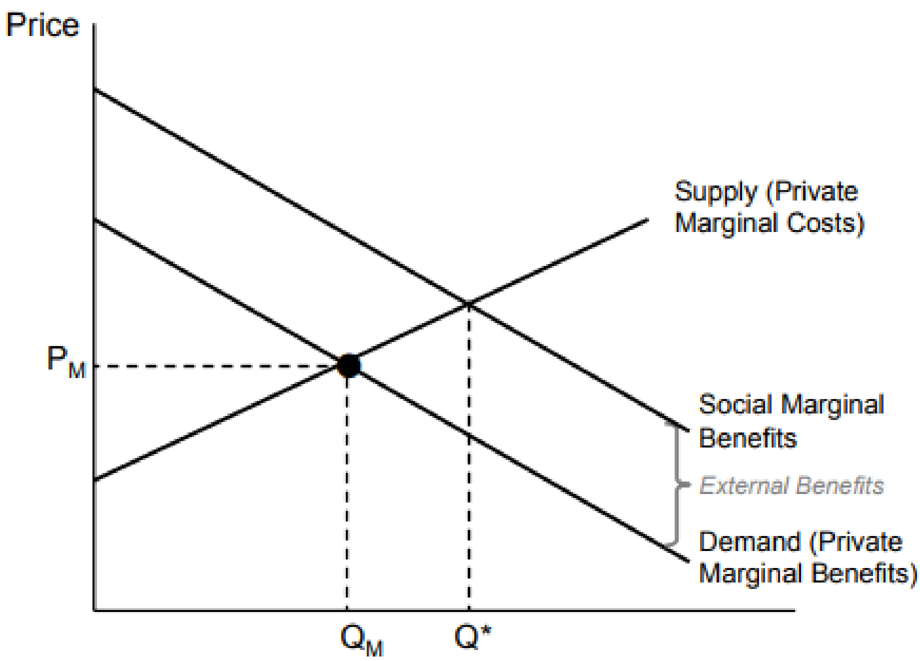


Figure 1 – Socially optimal equilibrium graph. Source: (Roach, Harris, & Codur, 2015)

Without consideration for the positive externalities the market will produce at the market quantity (Q_M), instead of the socially optimal quantity (Q_*). Hence there is a market failure and an economic rationale for potential government intervention.

Positive externalities occur with wetlands. When one enterprise installs a wetland the improvements in water quality are shared by all, even though they didn't pay for them. Hence, due to the presence of positive externalities, this would suggest there are less wetlands built than would be socially optimal.

3.2 Public goods, game theory and free riding

A cooperatively developed wetland has an aspect of a public good in that, without some kind of mechanism it is non-excludable, i.e. the wetland doesn't discriminate between mitigating the contaminants of those who contribute to the wetland development and those that don't. Pure public goods are both non-excludable and non-rival (Stiglitz & Rosengard, 2015). However, a wetland can be rival, as it only has a finite capacity to mitigate contaminants. Hence, a wetland is not a pure public good.

Nevertheless, without a way to exclude those who don't contribute there is an incentive to 'free ride'. Free riding is a concept used to describe a situation where an individual receives a benefit due to another's actions without having to pay a cost for this benefit. Free riding can occur in water quality situations if some individual enterprises take actions (such as building a wetland) that benefits the water quality of all, whilst other enterprises contribute no costs to this endeavour but still receive the water quality improvement benefits, i.e. the positive externalities. There is a strong incentive for people to free ride as water quality mitigations are often quite expensive.

Game theory entails many assumptions, key of which is that individuals are rational and are motivated by self-interest (Stiglitz & Rosengard, 2015). For the wetlands example if the enterprises in this catchment were to follow their individually rational solution then they may choose to not participate in the wetland construction and a non-socially optimal outcome would be reached.

The incentive to free ride can be demonstrated in a game theory matrix where there are two options for an individual enterprise; either to participate in the wetland construction or to not participate. A game theory matrix is set out below with the rows representing the choices of one player; individual A, and the columns representing the decisions of another player; individual B. For the purposes of keeping things simple let's say that the benefits received by anyone participating in the wetland are equal to '$60' worth of mitigation savings on their own properties[2]. Let us also assume that the costs of building and maintaining a wetland are '$80', which reflects the real world situation that the costs of building a large wetland are often more than any one participant can afford by themselves.

Hence the total net benefit received for one individual participating in the wetland is equal to -$20 (60-80) and $20 (60-40) if both participate, as the wetland development costs can be shared. If the wetland does not get built then neither individual receives any mitigation savings ($0). However, if one individual can benefit from the value of the wetland, i.e. the other individual builds it, without having to pay for the wetland, then their benefits for not participating are equal to the full $60, as they receive the mitigation savings while not having to pay for the wetland construction.

Hence the matrix would for this problem would look like:

	Participate (Individual B)	Don't participate (Individual B)
Participate (Individual A)	(20 , 20)	(-20, 60)
Don't participate (Individual A)	(60, -20)	(0, 0)

Figure 2 – Matrix for constructed wetland problem

[2] This could also be said to be the opportunity cost, i.e. the cost of the second best alternative.

As can be seen from the matrix, both individuals have dominant strategies to not participate in the wetland construction, as if either the wetland is built or not built it is better for them to not participate. However, this results in an equilibrium outcome of (0, 0) which is not as socially optimal as if both individuals had committed to participating (20, 20).

Hence without a mechanism to hold individuals to account for their individual contaminant losses, i.e. a means to exclude them from receiving the benefits of the wetland, the incentive to free ride is present. This may result in individuals not participating, to the detriment of all. Consequently there is a justification for a cooperative solution that allows those that wish to, to group together and commit to participating in the wetland development, whilst those that do not wish to participate are still individually responsible for their own contaminant losses.

The importance of dealing with free riders was a key point emphasised by interview participants. It is important to deal with free riders both for equity reasons and also for the purposes of ensuring that the catchment water quality targets are met. Interviewees came up with some suggestions for how to deal with the free riding problem.

> "When it comes to dealing with free riders, regulation, voluntary persuasion or exclusion are probably the options." – **Senior Policy Advisor (Waikato Regional Council)**

The most stringent option is regulation or forced participation in the wetland scheme. The argument for this option rests on it being in the public interest if everyone participates in the wetland scheme. Whilst this may or may not be true, many interviewees thought that forced participation was too heavy handed and defeated the point of a cooperative approach.

Another option suggested was voluntary persuasion, i.e. if someone is holding out from participating in the wetland scheme the strategy would be to convince them to participate without any compulsion. Positive peer pressure was seen by many as being a legitimate strategy for neighbours convincing neighbours to participate. However, most interviewees considered that voluntary options were not sufficient to achieve the results required.

The final option that interviewees suggested was exclusion or removal from the wetland scheme. This idea would necessitate first making everyone responsible for their individual contributions to the water quality issues. Then if people didn't want to participate they wouldn't have to, instead having to do individual mitigations on their own property. It would also allow groups to expel members if they did not end up contributing to the development costs, forcing those individuals to instead have to do individual mitigations on their property. This was by far and large the most preferred option interviewees thought should be used to deal with free riders.

3.3 Private cooperative action and cooperative group behaviour

The management of a large cooperatively developed wetland is similar to the management of common pool resources. Common pool resources are rival but without intervention are non-excludable, just like wetlands. Ostrom (1990) suggests that through the use of private cooperative action groups can successfully manage common pool resources and overcome problems such as free riding and the tragedy of the commons.

Generally, private cooperative action is suggested to occur as an alternative to government intervention. However, Ostrom, Cox, & Schlager (2014) note that in reality private cooperative action occurs against a backdrop of existing rules and layers of institutions and that groups can organise and find private cooperative solutions in such environments.

Hence, it is possible, as some interviewees suggest, to have a regulatory backup option in place in case limits are not met or outcomes are not achieved, whilst still having an institutional environment that supports private cooperative action.

3.3.1 Ostrom's principles for the design of effective groups

In Ostrom's legendary book, Governing the Commons (1990), she analysed a variety of empirical situations in which groups had formed independently of governments in order to manage and govern common pool resources. Using these studies she extracted eight core design principles for the effectiveness of groups regarding the management of natural resources (Wilson, Ostrom, & Cox, 2012). Groups did not necessarily have to incorporate all of the principles to be successful, however when these principles were present groups tended to have greater success (Ostrom, 1990).

Wilson, Ostrom & Cox (2012) go further and suggest that the eight principles have a wider range of application than just common pool resource groups but are equally relevant to other situations where group cooperation is required in order to achieve a shared goal. Hence they suggest that the principles can be used as a guide to increasing the effectiveness of groups, though they caution that local tailoring of the principles is usually required for implementation.

Ostrom's eight principles and a short description of each of them are outlined below:

1. Clearly defined boundaries. Groups are more successful when who is involved in the group (and who isn't) and the geographical scope of the group's influence is clear. Furthermore any additional boundaries need to be understood and agreed upon.
2. Proportional equivalence between benefits and costs. Groups are more successful when members feel like the costs they are paying are equivalent to the benefits received. Inequitable situations tend to negatively influence group dynamics.
3. Collective-choice arrangements. Groups are more successful when they get a say in creating the rules that govern them. "People hate being told what to do but will work hard for group goals that they have agreed upon" (Wilson, Ostrom, & Cox, 2012, p. 22)
4. Monitoring. Groups that don't have adequate monitoring risk being subject to the tragedy of the commons in which members of the group will take advantage and free ride or exploit the situation to their advantage. Hence groups that have a higher visibility of each other's contributions and can tell if someone is not doing what they said they would tend to be more successful.
5. Graduated sanctions. Groups tend to be more successful when sanctions begin at a low level, such as a reminder, and then escalate if the situation does not improve. Imposing a severe punishment at an early stage may be seen as unfair and will risk alienating the allies of the group member.
6. Conflict resolution mechanisms. Groups are more successful when they have well defined processes for resolving conflicts in a manner that is quick and fair.
7. Minimal recognition of rights to organise. In general groups should be given the authority and right to develop their own rules and institutions, rather than having these imposed on them

by government. Information and guidance from government is of course useful but the most important thing that government does not undermine local efforts.

8. Appropriate coordination between relevant levels of groups. Groups set up for a particular purpose have an optimal scale, for example government is split up between functions that work best at either a local, regional or national scale. Coordination is required between groups at different scales in order to achieve an effective outcome.

These principles are not new, they have been part of humanities evolutionary history for a long time (Wilson, Ostrom, & Cox, 2012). However, they are not always adopted by groups as “the design principles are not so obvious or instinctive that all groups quickly converge upon them” (Wilson, Ostrom, & Cox, 2012, p.27). Hence there is generally scope for the improvement of group processes by focusing on these principles and analysing where they could be placed in order to achieve an enhanced group working dynamics and outcomes.

The importance of principle 8, appropriate coordination between relevant levels of groups, is paramount to ensuring the optimality of group processes. This idea of many ‘spheres of activity’ at different scales is also known as polycentric governance. Wilson, Ostrom & Cox (2012) assert that there is no better option than polycentric governance and that many activities that are currently governed at a larger scale would be more effectively governed at a smaller scale. New Zealand has a relatively decentralised resource management process compared to many countries and hence a move to even more polycentric forms of governance would be easier to achieve. However, not everything can be achieved most efficiently at a smaller scale. Hence, the coordination between smaller scale groups and larger scale groups, particularly for services that can only be provided at that larger scale, is essential to the efficient functioning of those smaller groups.

Ostrom’s principles are such that they need to be embedded in the institutions of the group. It is not a simple linear approach to identify where these principles should be considered and/or applied.

3.3.2 The IAD framework

Frameworks are a useful means for creating a shared orientation for investigating policy issues via identifying and developing key categories of concepts. The Institutional Analysis and Development (IAD) framework is a tool, originally developed by Elinor and Vincent Ostrom, which assists in understanding the logic behind the design and performance of institutions (Ostrom, Cox, & Schlager, 2014). It is a tool that can help an analyst make informed suggestions for improving institutional performance.

The work of Ostrom, Cox & Schlager (2014) in their assessment and guidance on how to perform an IAD framework analysis will be relied upon heavily for this section of the research project, with a particular focus on aspects of the IAD framework that are relevant to the cooperative development of large wetlands.

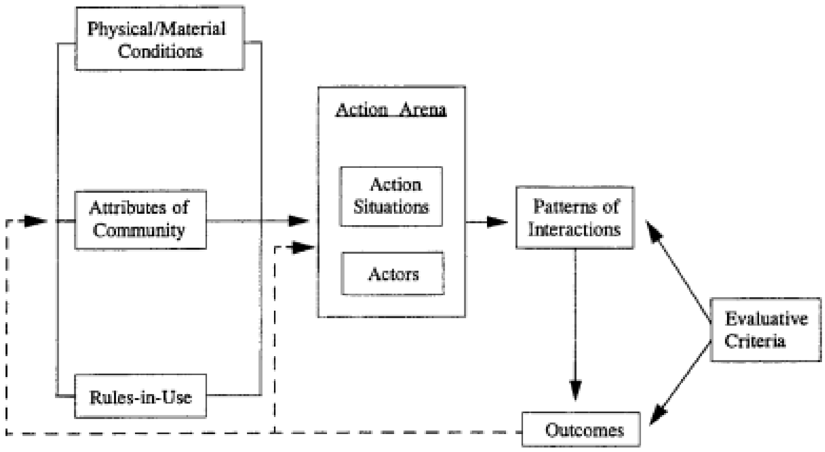


Figure 3 – The IAD Framework. Source: Ostrom, Cox & Schlager (2014)

Action Arena

An action arena is a social construct that outlines how individuals and organisations (or 'actors') interact with each other in order to address policy issues. The action arena is the focal point for analysis under the IAD framework (Ostrom, Cox, & Schlager, 2014). An action arena is composed of an action situation(s) and the actors involved in that situation.

For the purposes of this research this research will focus on one action arena which will be comprised of multiple action situations and actors. The action arena that will be focused on is how individuals and organisations would interact with each other in order to cooperatively develop a large constructed wetland for the purposes of improving water quality in a cost effective manner.

Action Situation

An action situation occurs when actors interact in the pursuit of an outcome. The structure of an action situation is determined by a set of seven variables that are the 'givens' that the analyst uses to describe the situation. These variables are:

1. The set of participants involved in the situation.
2. The specific positions that exist in the group.
3. The set of allowable actions that could be taken.

4. The potential outcomes that could occur.
5. The level of control over choice that participants have.
6. The information available to participants about the structure of the action situation.
7. The costs and benefits which serve as incentives and deterrents to actions and outcomes.

The Actors

In the IAD framework, actors are the factor that sets the action situation in motion through their interactions (Ostrom, Cox, & Schlager, 2014). Actors can be either individuals, groups of individuals or organisations. The set of participants identified in variable 1 of the action situation are taken from the pool of actors and may include all or only some of the actors for a particular action situation.

The IAD framework doesn't dictate how an analyst should view the decision-making of actors. Instead the analyst must make assumptions about and explicitly identify actor's values, capabilities, resources and their internal mechanisms used to decide upon strategies (Ostrom, Cox, & Schlager, 2014). Understanding how each actor views the world and the extent to which they value gains to themselves versus gains to their community is important when analysing how actors will act. In reality most people value gains to their community as well as gains to themselves, but are only willing to sacrifice their private gain for the communities gain up to a point.

This relates to the concept of bounded rationality. Actors are rational up to a point but have limited information and are often unsure how to reach the outcomes that will best meet their needs. Over time actors can acquire more information to make better informed decisions and can reciprocate when other actors do something that affects them positively (or negatively). Hence narrow, short-sighted decisions of self-interest tend to occur less under these circumstances.

Furthermore, individuals and organisations don't make decisions in a vacuum. Decisions are made in communities, regions and countries where embedded norms and cultures influence the outcomes. This broadens the range of strategies that actors might adopt.

Evaluative criteria

Evaluative criteria are a significant feature of the IAD framework that should be considered when assessing whether or not a given intervention and set of institutional arrangements is optimal for achieving an outcome. However, the desired outcome, improving water quality by a given amount for the least possible cost, is known. Also the intervention to achieve this outcome, the cooperatively developed wetland, has been set for the purposes of this research paper. Hence a comparison of different interventions for achieving the outcome against evaluative criteria is beyond the scope of this paper. Nonetheless, a short investigation of evaluative criteria for a cooperatively developed wetland is provided in Appendix 2.

One learning that is important to note from Ostrom, Cox and Schlager (2014) is that it is not possible to design institutions that will fulfil all of the criteria as there will inevitably be trade-offs.

Exogenous variables affecting Action Arenas

There are three exogenous variables that affect action arenas; the rules in use, the physical and material conditions, and the nature of the community. These variables all affect the types of actions that actors can take, costs and benefits of certain actions and the impacts on outcomes (Ostrom, Cox, & Schlager, 2014)

Rules

Rules are "shared understandings among those involved that refer to enforced prescriptions about what actions or physical and material conditions are required, prohibited, or permitted" (Ostrom, Cox, & Schlager, 2014, p. 277). There are formal rules, such as legislation, but there are also informal rules that actors can place on themselves or each other, e.g. industry codes of practice. Rules change over time as actors figure out better ways to accomplish the outcomes compared to previous ways.

All of the 'rules-in-use' are "nested in another set of rules that define how the first set of rules can be changed" (Ostrom, Cox, & Schlager, 2014, p. 284). Kiser and Ostrom (1982) outline three levels of rules; operational rules that affect day-to-day decisions, collective-choice rules that affect operational rules and how they might be altered, and constitutional-choice rules that affect operational rules as well as collective-choice rules and how they might be altered.

The IAD framework also has a class of rules called 'working rules' which refer to what participants in a cooperative private action solution use to determine their behaviour regarding the cooperative group process. There are seven types of working rules that can affect an action arena; entry and exit rules, position rules, aggregation rules, information rules, payoff rules, authority (or choice) rules and scope rules (Ostrom, Cox, & Schlager, 2014).

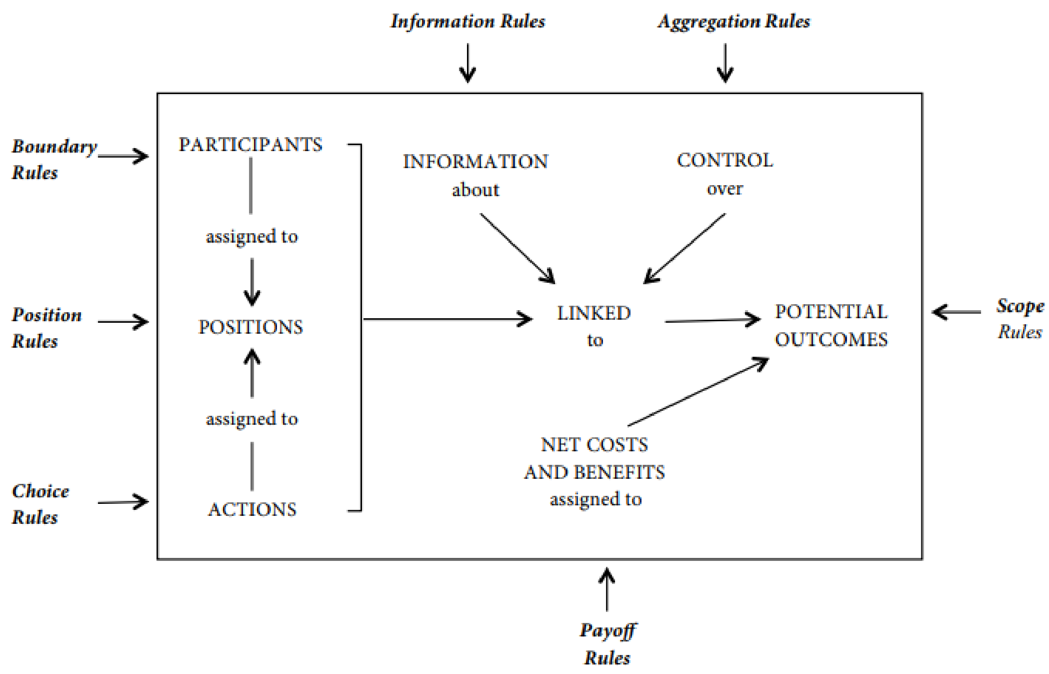


Figure 4 – Working rules affecting action arenas. Source: Ostrom, Cox & Schlager (2014)

Entry and exit rules affect the participants in the cooperative group; how actors can gain entry into the group and the process for exiting the group, e.g. if a landowner wishes to leave the wetland scheme. Position rules cover the particular roles that are required in the cooperative group, e.g. chairperson, treasurer, enforcer etc. Aggregation rules affect how much control each individual has over their potential actions regarding the cooperative group, e.g. certain actions (such as delegating a position role if going on holiday) may require group approval. Information rules affect how much participants know and reveal about themselves and the group, e.g. some information is made public and some information is kept private. Payoff rules affect how the specifics of how benefits and costs will be assigned and hence have flow on effects on incentives, e.g. allocation of maintenance costs.

Some working rules are assigned from a higher institutional level, most likely the regional council in the case of a cooperative wetland. Authority rules assign to the cooperative group certain actions that must or must not be performed, e.g. certain monitoring requirements must be met. Scope rules bound the potential outcomes and the actions of the group, e.g. certain water quality limits must be achieved by a given timeframe.

Working rules work together in combination. Hence a change in one rule may require approval from another rule or may have flow on effects on the other rules. There is increased stability in cooperative groups that interact according to a mutually agreed to set of rules.

Physical and Material Conditions

Many of the variables within an action arena are also affected by the attributes of the physical and material world (Ostrom, Cox, & Schlager, 2014). The physical world we live in limits the actions that are possible and the outcomes that can be achieved. The same set of rules may lead to completely different outcomes in different physical and material conditions.

There are two attributes of the physical and material conditions that commonly affect the incentives of actors in public good or common pool resource situations; excludability and subtractability of flow. Both of these attributes relate to the ability of the cooperative group to deal with the potential for free riding, which has already been extensively covered in section 3.2. Hence, only a short discourse on these two attributes will be provided.

Excludability

Wetlands will mitigate contaminants from a watercourse regardless of who contributes to the cost of building them. Hence, as discussed earlier, any potential solution needs to have some means of excluding free riders from receiving the benefits of the cooperative wetland development process.

Subtractability of flow

Wetlands have a finite capacity to assimilate contaminants. Hence when one resource user subtracts from the flow of the resource, e.g. the wetland’s assimilative capacity, it means that there is less available for other resource users.

When demand for such a resource is greater than supply it can create an incentive for users to use as much of the flow as they can as they fear that it may not be available later. Hence, when a resource is affected by subtractability of flow, effective institutional arrangements are required to ensure that the resource is not over used and is allocated in an efficient and equitable way.

Additional Attributes

There are many additional aspects of the physical and material conditions that would affect the combinations of rules and action situations that are possible and desirable. These include aspects such as topography and the number of participants. Given that it is assumed (Assumption 1) that the efficacy of wetlands is established it is not necessary for the purposes of this research paper to discuss these additional attributes further (though some discussion is provided in Appendix 1).

However, it is worth noting that the physical and material conditions are always going to be different in some regard in each setting and hence it is important to ensure that institutions can be tailored to suit different situations rather than assuming uniformity (Ostrom, Cox, & Schlager, 2014).

Attributes of the Community

The term culture is often applied to the bundle of variables that are the attributes of the community (Ostrom, Cox, & Schlager, 2014). Some of these variables include the norms of behaviour within a community, the amount of common understanding that participants have about issues, the extent to which the individuals have similar preferences and how resources are currently distributed between them.

When individuals and organisations in a given community share similar values and already have existing (hopefully positive) relationships formed from working together in other capacities, the probability of developing workable rules to govern resources is much higher (Ostrom, Cox, & Schlager, 2014). Furthermore when individuals frequently interact the importance of honesty is increased and hence the cost of monitoring and enforcement measures is likely to be less.

4 Analysis

This section of the research paper utilises IAD framework analysis, an application of Ostrom's 8 principles and the findings from the interviewing process to analyse the cooperative wetland development solution. This section outlines a pathway through which a cooperatively developed wetland could be constructed and highlights the opportunities and challenges that would likely arise at each stage. The Moakurarua worked example is used throughout this section to show how each stage might play out in a real world situation.

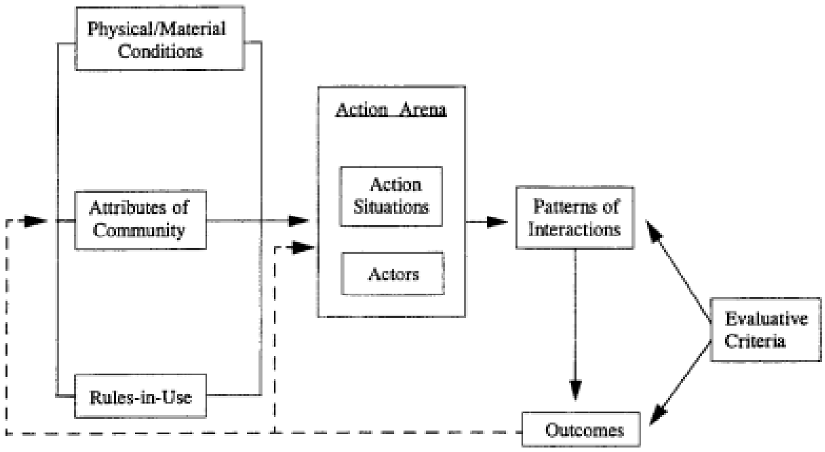


Figure 5 – The IAD Framework. Source: Ostrom, Cox & Schlager (2014)

4.1 Desired outcome

In this case the desired outcome under the IAD framework is known. The shared problem that the actors are trying to address is how to improve water quality by a given amount for the least possible cost. The method to achieve this outcome is the cooperatively developed wetland.

All interviewees recognised that wetlands are an important part of the solution and could be cheaper and more effective than doing individual property level mitigations. Interviewees recognised that it is key for multiple parties to work together in order to achieve the least cost solution for a particular subcatchment.

> "If everyone took only focused on their individual contributions then the costs of doing this [improving water quality] could be far larger than building a wetland. One solution could be cheaper than lots of little things" – **Dairy Farmer**

4.2 Pre-feasibility study

Interviewees highlighted that it is important to first know, understand and communicate what the water quality issues are before trying to address them. Furthermore, each subcatchment has its own water quality profile with its own issues and solutions to address these issues. Hence some kind of pre-feasibility study is needed, that identifies issues in particular subcatchments, and that identifies at a broad level whether or not a large constructed wetland is at least potentially viable.

> "It is important to look at what the issues are before looking at what the solutions could be" – **Environmental Extension Specialist (Dairy NZ)**

Fred is an employee of the Waikato Regional Council. Fred[3] is asked to undertake a pre-feasibility study for the Moakurarua subcatchment to try and ascertain whether or not this subcatchment might be suitable for a large cooperatively developed constructed wetland. Fred undertakes some analysis and finds that in the Moakurarua subcatchment sediment is the contaminant that is needing to be reduced the most (62%) and nitrogen is the contaminant that is needing to be reduced the least (35%). Hence Fred concludes that any solutions for this subcatchment need to recognise that sediment is the main contaminant that needs to be targeted and that a constructed wetland with an easily cleaned sediment trap would be effective at addressing this subcatchments particular issues.

4.2.1 IAD framework – Physical Conditions

Cooperatively developed wetlands require knowledge about some of the particular physical conditions. There will be some subcatchments in which the particular physical conditions will determine that building a wetland is either not feasible or not the most efficient mitigation option for that subcatchment. However even subcatchments that are feasible for wetlands will need to account for the physical conditions in order to determine the most effective location and design of the wetland. Every subcatchment will have different conditions and hence each wetland design will be need to be unique to respond to these different conditions. As many interview participants noted, wetland design is very 'horses for courses'.

A scientific assessment would need to take place following on from the prefeasibility study in order to determine where and how a wetland should be placed. For the purposes of this research report a subset of the most important physical conditions that scientists would to assess are laid out below in order to give the reader an idea of the kind of conditions that would need to be assessed. These conditions include:

- Size of the subcatchment. The size of subcatchment will have an influence on the size of the wetland required. Furthermore, a subcatchment that is too small may not warrant a large

[3] In reality the pre-feasibility study would likely be undertaken by a multi-disciplinary team.

wetland approach and a subcatchment that is too large may require more than one wetland for its needs.

- Topography of the subcatchment. The amounts of flats, rolling hills and steeper hills and the land use classes in the subcatchment will influence where the wetland is placed and how effective it is at reducing the flow of water, which is needed for sediment to settle and nutrient uptake by plants.
- Types and quantities of enterprises in the subcatchment, both past and present. Subcatchments with different enterprises will have different issues. Subcatchments that have more dairy enterprises may have more issues with nitrogen, whereas subcatchments that have more sheep and beef enterprises may have more issues with sediment. Furthermore, if the subcatchment had different enterprises previously there may be legacy issues in terms of the 'load to come' in the groundwater. Hence the design of the wetland will need to account for any 'load to come' when figuring out how much nutrients it can handle, in order to be most effective.
- The level of existing water quality degradation. The extent of water quality degradation and the makeup of the contaminants that are the issues will influence both the size and the design of the wetland, e.g. if sediment is a large issue than there may need to be sediment traps put in at the top end of the wetland.
- The amount the subcatchment contributes to degradation downstream. Subcatchment targets incorporate reductions based on both what is required in that subcatchment to meet water quality limits as well as reductions based on contributions to downstream issues. To solve issues in the mainstream of the Waikato River, for example, requires reductions in the tributaries. Hence a wetland may need to be designed differently as a result of considering the conditions downstream.
- Groundwater. There are many aspects of groundwater aquifers that would require understanding. How deep are the aquifers and what are the resulting time lags for their contributions to water quality issues? What is the quantity of water contained in the aquifers and how does this contribute to the flow and quantity of water in the subcatchment? What is the direction of flow of groundwater, i.e. does water flow into or out of the wetland from groundwater, and does this change at different times of the year or when the river is at different levels?
- The presence or absence of existing water quality monitoring sites may influence where the wetland is located. Whilst new monitoring sites could be added it is more cost-effective to utilise existing sites if possible.
- The quantity and reliability of surface water flow. This condition will influence how effective the wetland can be at reducing the flow of water. Furthermore, the reliability of the flow of water is a key condition for the location of the wetland.
- The level of water quantity during storm surges (and any existing flood mitigations). Wetlands can 'blow out' during storm surges and hence are often designed to be able to cope with a certain level of flood risk (e.g. 1 in 50 year floods). Floods carry many of the contaminants that wetlands will be designed to mitigate, particularly *E.coli* and sediment. Hence it is desirable for a wetland to be designed in a way that it can handle a certain level of flooding in order to absorb these contaminants. But the wetland needs to also have a means of diverting the flow of water if the peak flows go above a certain level in order to avoid 'blowing out'.
- The presence or absence of pest plants and/or fish. Pest plants and fish can impact upon the effectiveness of a wetland and hence the design of a wetland may need to take into account

their presence with more resilient plants or a pest control programme may need to be established in conjunction with the wetland development.

The number of participants in a given scheme is also important to consider. Too few participants and the level of mitigation required may be too small to warrant a large wetland. Too many participants would increase transaction costs and the complexity of the institutional arrangements.

Fred, the WRC worker, analyses the topography and geography of the subcatchment with the help of a scientist and they find several spots that might be suitable for a large constructed wetland. Fred then looks at the enterprises around those spots and eliminates some that would likely have too few contributing enterprises to make the wetland cost effective. The scientist undertakes an initial high level assessment of what is known about some of the scientific aspects of the physical conditions such as the groundwater aquifers and presence/absence of pest fish/plants. Finally, Fred looks at the existing monitoring sites and notes which potential wetland spots would have the advantage of existing water quality monitoring data and which would require a completely new water quality monitoring point. Fred narrows the initial list of potential sites down to a shortlist.

4.2.2 IAD framework – Material conditions

A pre-feasibility study should also highlight at a broad level what the potential costs and benefits of the large constructed wetland could be.

One of the questions that interviewees were asked about was what would incentivise people to participate in a cooperative wetland development scheme for improving water quality. Whilst interviewees noted a number of incentives, the financial incentive, i.e. participating in the wetland development is cheaper than performing individual mitigations, was identified as the biggest incentive for participating in the scheme.

> "The financial incentive is the biggest incentive, but you would need to prove that it is the cost-effective solution." – **Principal Economist (Waikato Regional Council)**

Hence confirming that a large constructed wetland has the potential to be part of the least cost solution upfront in the pre-feasibility study will provide the incentive for private land owners to investigate this mitigation option further for a particular subcatchment.

Now that Fred has identified a shortlist for a potential wetland sites from a scientific point of view, he undertakes a broad level cost-benefit analysis to determine what the potential costs of the wetland development would be at each site, and what benefits would accrue as well. As part of the pre-feasibility report Fred makes a recommendation for where the initial scientific and economic assessment indicates the location of the wetland should be.

4.2.3 Ostrom Principle 1 – Clearly defined boundaries

A pre-feasibility study helps fulfil Ostrom's first principle of clearly defined boundaries. The participants of the wetland development group and the geographical boundaries of the subcatchment will be clearly defined under a pre-feasibility study. The regional council will also need to make clear what the limits and targets of the subcatchment are, so that the pre-feasibility study can assess what effect the wetland would have on meeting those targets.

4.3 Stage 1 – Formation of the cooperative group

Once a pre-feasibility study has been completed the first stage of a cooperative wetland development process is to form the cooperative group. It is important to engage the community in the constructed wetland process. Achieving 'buy-in', or agreement to proceed, to the idea is important in order to get the process off the ground, ensure the longevity of the wetland and provide legitimacy to the water quality solution. Some interviewees noted that communities themselves are the ones best placed to achieve this 'buy-in' and hence targeting community leaders first, in order to spearhead the endeavour, is a good practice approach.

> "Got to engage the leaders in the community. Start by engaging them. There are always leaders" – **Sheep and Beef Farmer**

4.3.1 IAD framework – Attributes of the community

The attributes of a given community will influence the design and operating effectiveness of the wetland cooperative group.

Communities that have worked together in other capacities will be more effective at working together for the development of a wetland. These communities will already have some of the norms in place that will encourage effective cooperation, such as respecting each other and being open to new information and ideas.

However, if there have been bad previous experiences or there are neighbours who simply do not get along and can't work together this will make a cooperative process very difficult. In some cases it may make the development of a wetland impossible

Several interviewees noted that the social aspects related to the wetland scheme are at least, if not more, important than the scientific aspects. There were several elements of the social side that interviewees noted were important to consider.

One of these was that the need to improve water quality is not fully understood by all landowners yet. People are overwhelmed with information and scared at what the implications of being forced to install expensive mitigations might be for their business. Considering these factors, and providing a decent level of support, is important to achieving 'buy-in'. The importance of support from government in terms of both funding and technical assistance was also a key area of agreement between interviewees.

There is also a lot of attention from the general public on water quality and the environmental impacts of farming at present. Socially sustainable farming and having the social license to operate is more important than ever for farmers to understand and internalise into their businesses.

4.3.2 Ostrom Principle 7 – Minimal recognition of rights to organise

It is important for government to recognise the rights of the cooperative group to organise. This principle requires that governments recognise that local groups are, in general, best placed to develop rules and institutions for their local circumstances. Hence unless there is a cause for aggregation these aspects should be left in the domain of the local communities.

4.3.3 IAD framework – Actors

The key actors in a cooperative wetland development scheme will be the land owners in the subcatchment who are interested in participating in the scheme. Other actors could include industry bodies, local councils and NGO groups.

Part of the negotiations that actors will have to undertake will involve understanding each other's positions and developing empathy for each other's situations.

Furthermore, when actors are in agreement about the legitimacy of boundaries and there is reliable monitoring, this is more likely to result in higher levels of cooperation and better governance of common pool resources (Ostrom, Cox, & Schlager, 2014). This is a key component in the uptake of this kind of scheme.

4.3.4 IAD framework – Action situations

The key action situation for the wetland development scheme is the formation and operation of the cooperative group. This action situation will play out differently in different circumstances but some of key variables will be outlined in this section in order to show what the situation might look like.

1. Set of participants:
    - Land owners in the subcatchment (dairy, sheep and beef, forestry, horticulture, other)
    - Point sources (wastewater treatment plants, industry, other)
    - Local iwi and hapū
    - Community and recreational users (including any local or downstream streamcare groups)
    - Government. District, Regional and Central
    - Industry groups, e.g. Dairy NZ, Beef + Lamb, Horticulture NZ

2. Specific positions:
    - Members of wetland management group, including positions such as a chairman, treasurer, secretary, etc.
    - Holders of the wetland (those with it on their property)
    - Maintenance crew
    - Coordination of wetland development
    - Monitoring of contributions to costs, wetland development, scientific monitoring, monitoring of other actions required

3. Set of allowable actions:
    - Certain existing practices are controlled under the current regional plan, e.g. earthworks, effluent rules etc.
    - All farmers with dairy, beef, deer or pigs are required to fence their streams, drains and wetlands under the new regional and national legislation.

- All farms will need a farm environmental plan that will set out the contaminant risks on their properties and contain actions that will reduce the amount of contaminants leaving their properties.
- There are subcatchment limits and targets with stages to meet these targets.

4. The potential outcomes:
   - By putting in a large constructed wetland the land owners would improve water quality at a lower cost than doing individual mitigations on their own properties

5. Level of control over choice:
   - As noted in Assumption 3, it is assumed that in the future all enterprises will know their individual reductions required to meet the subcatchment limits.
   - Most land owners would have control over the choice as to how they wish to meet any reduction goals.

6. Information available to participants about the structure of the action situation:
   - Some participants know more than others but in general there is lack of understanding of the key aspects of the situation such as good environmental farming practice, the rules in the Healthy Rivers plan change, the science aspects regarding contaminant losses and the benefits of wetlands relative to other mitigations.

7. Costs and benefits which serve as incentives and deterrents:
   - There are some easy wins to be had on some farms, and even some win-wins in some situations (such as improved P management). However most of the mitigations required will require significant time and cost.
   - Farmers often don't know all of the mitigation options available and it can be hard to be certain about some of the benefits.
   - Furthermore subcatchment actions, such as large constructed wetlands, are even less understood in terms of costs and benefits than on farm mitigations

Naomi is a dairy farmer in the Moakurarua catchment. She's heavily involved in the local community and hears about the pre-feasibility study that has been done. She knows that her farm faces large potential mitigation costs even though she has already implemented several mitigations on it. Naomi decides to call up her neighbour, Phillip, who is a sheep and beef farmer. She explains the opportunity to Phillip and they decide to organise a meeting with other local land owners to decide whether or not the wetland option is worth investigating further. Naomi invites Fred and his team from the regional council to come to the meeting in order to provide some information on what the cooperative wetland scheme might look like. At the meeting the land owners decide they will form a cooperative group and arrange to meet several more times in order to progress the scheme.

4.3.5 IAD framework – Rules in use

For the cooperative development of large wetlands both formal and informal rules will be required in order to ensure the effective running of a cooperative group.

There will be some formal rules that will be required or desired in order to ensure the success of the scheme. These importantly include the subcatchment limits and targets and rules that wetlands can be used to meet these targets.

There will also be some informal rules that will be required or desired. For example:

- Guidelines around monitoring the wetland from the regional council or an independent science organisation such as NIWA
- Industry codes of practice that outline how to include a wetland into a farm environment plan or OVERSEER™ file.
- Planting and maintenance guidelines

The working rules for the wetland scheme will also be important. Again these could need to be different depending on the different circumstances.

There is no one set of rules that can be plucked off the shelf and used. The importance of flexibility of rules, between both situations and over time, cannot be overstated. Furthermore it is vital that communities have a say in designing the rules that they will have to abide by.

4.3.6 Ostrom Principle 3 – Collective-choice arrangements

The formation of the cooperative group and the design by the group of effective group decision making mechanisms, such as an agreed upon terms of reference, will assist in achieving this principle. Groups should be given the ability to develop their own rules to the maximum extent possible. Though it may be desirable to have some examples of successful collective-choice arrangements provided by the regional council or industry bodies that cooperative groups could pick and choose between. Some groups may require more assistance than others and the regional council and industry bodies should be prepared to step in with support should it be required.

Naomi, Phillip and the other land owners meet to discuss what principles the group will have when cooperating with each other. They lay down the groundwork for developing rules and make guidelines for ways of working. In their next meeting the group discusses and creates some working rules. They note the scope and authority rules, including the required limits and targets, which the regional council have set. They create some entry and exit rules, including a rule saying that any enterprise wishing to leave the wetland scheme must find a willing buyer for their share in it. The group discuss the roles that would be required and decide they need a chairperson, secretary and treasurer. They begin a nomination and election process for getting people into those roles.

4.3.7 Ostrom Principle 6 – Conflict resolution mechanisms

Disagreements are inevitable in a complex process such as this and there should be clear processes for resolving these disagreements. Having, as a back-up, facilitators or experts in conflict resolution available to assist groups in this regard could be a good role for either council or industry groups.

Naomi, now the elected chairperson of the cooperative group, complies the draft set of rules that the group has developed so far. The group has one final meeting to decide the rules and the group's terms of reference. After some long discussions, and several alterations, the group agrees upon a terms of reference with a set of rules for operating and some agreed conflict resolution mechanisms.

4.3.8 Importance of maintenance and a long term strategy

An aspect that was regularly emphasised by interviewees was the importance of planning for the long term and the need to develop a long term strategy when looking at developing a wetland. Part of this would include the long term maintenance of the wetland (e.g. clearing sediment traps and weed control) in order to keep it at peak effectiveness.

Wetlands are a constantly changing environment and they are always evolving. A long term strategy would assist with prolonging the long term effectiveness of the wetland, e.g. harvesting plants after two decades. With good monitoring and maintenance wetlands can function most effectively.

Naomi and Sharon, a local iwi member who also was elected the group's treasurer, work together to develop a long term budget and strategy for the Moakurarua wetland. They include a maintenance component to this strategy that involves harvesting/replanting plants every 20 years and clearing sediment traps every 10 years. They take the strategy to the group to be discussed, tweaked and agreed upon.

4.4 Stage 2 – Options for wetland design

Once the cooperative group has decided upon some basic operating rules, options for wetland design can begin to be looked at. Expert advice would be needed at this stage to develop a range of options that would be good at achieving particular objectives. For example a maximum cost-effectiveness option could be investigated, i.e. where investment in the wetland would occur until the point when between the on-farm mitigation and the wetland, there is compliance with the targets, and the last dollar spent on the wetland is equivalent in mitigation terms to the last dollar spent on the on-farm mitigations.

4.4.1 Include all contributors

It will be important to include all contributors in thinking about how to achieve the best wetland design. Interviewees highlighted that there was likely to be a mix of enterprises and contributors to water quality issues in different sub catchments and that all contributors to the issues should contribute to the solution.

4.4.2 Potential for point source offsets

The potential for point sources (such as wastewater treatment plants or industry) who are downstream from the wetland to contribute to its development was also mooted. The idea being that

> "A point source, like a wastewater treatment plant, could contribute to the wetland to offset their contributions." – **Policy Manager (Waikato Regional Council)**

upgrading point source treatment processes, particularly for point sources that already have advanced treatment processes, can be extremely expensive and it may be a more effective option to invest the same money (or a proportion of it) in wetlands. Point sources from industry, such as milk factories, could even run programmes where they pay for a proportion of their farmer's wetland development costs instead of upgrading the treatment capacity of the plant.

Many interviewees thought that this would be an effective solution and should be allowed to occur. Some however stressed that point sources can put a lot of environmental pressure on their local area and that this would need to be considered when looking at offsets, in order to ensure that the point source locales are not too impacted as a result of the offset and still meet local water quality targets.

4.4.3 Highlight the additional co-benefits

Interviewees also highlighted many additional benefits from wetlands that come alongside water quality benefits, such as biodiversity gains and potential carbon sequestration. Many interviewees noted that it was important to highlight these additional benefits as well, looking at all environment issues together when investigating potential solutions.

"The co-benefit of the biodiversity gain could be very substantial – **Land Management Advisory Services Team Leader (Waikato Regional Council)**

There is also potential for recreation co-benefits. Having aspects such as walkways, duck shooting areas, open swimming areas or picnic spots included in the wetland design would add to the total benefits of the wetland scheme.

4.4.4 Funding from external sources

Furthermore interviewees highlighted that there was a lot of potential for these wetland schemes to receive funding and/or assistance from external sources. Considering the potential for cost-effective water quality improvements that wetlands provide and the public benefits that are created from improved water quality, there is a good justification for funding from public or charitable sources.

4.4.5 Allow for innovative ideas

Some interviewees had innovative ideas for other ways the wetland could be used that would complement the water quality improvements. Include other aspects into the wetland design such as harvestable flax or watercress that could be collected at regular (or occasional) intervals and achieve an economic/social co-benefit that would also recycle nutrients and allow the wetland to function better as a nutrient sink. The inclusion of Manuka trees for honey around the outside of the wetland was also brought up as another possibility for an economic co-benefit.

Mitchell is another member of the Moakurarua cooperative group. He pitches an idea to the group to grow watercress beds and Manuka honey trees. He suggests that any money gained from these operations could be used to create a swimming area that local children could use. Sharon likes this idea and talks to the local council about co-funding the development of the swimming area.

4.5 Stage 3 – Apportionment of costs and benefits

Following on from making some decisions on the design of the wetland the group would then need to decide on how to apportion the costs and mitigation savings.

4.5.1 Ostrom Principle 2 – Proportional equivalence between benefits and costs

When considering apportionment it is important to take into account Ostrom's principle of achieving proportional equivalence between benefits and costs. The concept of equity is important to consider for this principle, e.g. if one land enterprise is paying more costs, then it follows that they should be receiving more benefits. A comprehensive assessment of the benefits and costs that includes non-direct benefits (such as biodiversity) and non-direct costs (such as any time spent planting) will assist with achieving this principle, and identifying not only landowner benefits and costs but also the potential benefits and costs to the wider community.

4.5.2 Compensation for those who give up land

It was generally accepted by interviewees that, whilst it is likely that the land the wetland would sit on would most probably be prone to wetness and of less value than regular pasture, those who have to give up their land for the cooperative wetland should be compensated for this. This could be monetary compensation, in-kind support or reduced contributions to the wetland development.

> "Some farmers could compensate others for the land lost" – **Sustainable Agriculture Advisor (Waikato Regional Council)**

4.5.3 Importance of flexibility

Flexibility was stressed by interviewees as being a key element of an enduring solution. This was flexibility in terms of both communities being able to decide upon the best solutions for their particular local conditions, as well as business flexibility to meet water quality objectives. Some interviewees also suggested that flexibility across the contaminants was important and as long as there was a net benefit to the environment this should be allowed. A net benefit to the environment could be determined by assessing what the effect would be on outcomes. For example, if a land owner increased their Nitrogen usage by 10% but reduced their Phosphorus usage by 15% and this resulted in less nuisance plant matter growth in the river, all other things being equal, a net benefit to the environment could be said to have occurred. However, questions remain about how difficult and expensive net-benefit assessments would be and who would make decisions about net-benefit trade-offs if they occurred, e.g. increased swimmability but decreased ecosystem health.

> "Flexibility across the contaminants is important to have, as long as there is a net benefit to the environment at the end of day" – **Sheep and Beef Farmer**

Whether or not flexibility should be further extended to allow for additional production, which would be mitigated by increased contributions to the wetland development, was a subject interviewees were divided on. Some thought that if best practice was being achieved on farm and there was no net-loss to the river, then additional production should be allowed. Others thought that building a wetland should be only done for the purposes of improving water quality and that additional production, regardless of the circumstances, shouldn't be allowed. Some interviewees thought that wetlands shouldn't 'prop up' unsustainable farm systems and that additional production might create hotspots upstream from the wetland. There was an emphasis that upstream of the wetland would still need to be swimmable.

4.5.4 Potential for trading

Some interviewees noted the potential for trading that the wetland provides. For example, landowner A could pay for the some of the share of landowner B's contributions to wetland in exchange for being allowed to emit more on their property and landowner B reducing their contributions on their property. Interviewees noted that people will work out if it is cheaper for them to use the wetland or other mitigations. Buying more of the wetland potentially allows for more business flexibility on farm.

4.6 Stage 4 – Finalising the agreement, monitoring and enforcement

The final stage is to finish off the specifics of the agreement and to develop a monitoring and enforcement plan.

Interviewees raised numerous questions about what the specifics would be for the agreement which would organise the cooperative wetland development. At the end of the day each cooperative group will be different and they would need to account for the differences in situations and preferences in each subcatchment. Nevertheless there are some questions are worth noting here to highlight the aspects that cooperative groups would need to debate, discuss and decide upon:

- What form would the agreement take? Would it be a contract, a consent (either global or individual), something else?
- Would it be legally binding and/or hold individuals to account for the contributions of other individuals?
- What would be the exit and entry rules be for the agreement?
- Could you put covenants on the titles of land owners in order to ensure that the agreement lasts even if the land is sold?
- Would multiple ownership of the land the wetland sits on be a possibility?
- Who would be responsible for maintenance for the wetland?
- There are inevitably going to be variations year to year in how farming enterprises run and their resulting losses. How would this be worked into the agreement?
- What mechanism could you use to enforce breaches of the agreement?
- What would be the allocation of liability if the wetland 'blows out'?

4.6.1 Ostrom Principle 4 – Monitoring

Monitoring of both actions and the results of those actions, via water quality monitoring, will be necessary. This could be carried out by a number of parties, e.g. the regional council, industry groups, an independent body or the landowners themselves. In regards to the actions to achieve results it is arguably more efficient for the landowners to undertake this monitoring as they are on the ground and are able to monitor actions, such as weed maintenance, for a relatively low cost.

The importance of have frequent and accurate in-stream water quality monitoring was highlighted by interviewees. The expense of water quality monitoring was noted, though some noted that it is also expensive not to have monitoring in terms of time spent arguing over the science. It was noted that, in the long term, real time monitoring could have a key part to play in water quality management.

4.6.2 Ostrom Principle 5 – Graduated sanctions

Enforcement mechanisms and sanctions are necessary in order to remove any incentives to free ride. Ostrom talks about using graduated sanctions, i.e. sanctions should escalate based on both the number and severity of the breaches of the agreement. For instance, a first time minor breach of the agreement could receive just a reminder. Whilst some enforcement mechanisms for breaches of the agreement might come from sources other than the cooperative group, i.e. the council or an industry group, the final enforcement mechanism (expulsion from the group) should rest in the hands of the group itself.

4.6.3 Ostrom Principle 8 – Appropriate coordination between levels of groups

There will be many levels of groups in a cooperative wetland development situation. The smallest scale of group, and most important group, will be the wetland development group themselves. The largest scale of group is central government as they are responsible for the legislative environment (e.g. the RMA) and providing direction (e.g. via an NPS) to regional councils. Furthermore, central government is responsible for providing national level scientific guidance, e.g. improvements to OVERSEER™. There will be groups in between or adjacent to these levels as well, for instance regional councils, catchment committees and iwi environmental management groups. It could well be the case that many subcatchment wetland development groups report their progress to a catchment committee which then reports, along with other catchment committees, to the regional council. Regional councils and catchment committees can provide guidance, rules and support to wetland development groups too, i.e. the flow of information is both ways.

The Moakurarua cooperative group agrees that it will provide a quarterly written report on progress to the Waipa Catchment Committee. The Waipa Catchment Committee compiles all of the wetland reports that it has received and reports on FMU level progress to meeting limits and targets to the Integrated Catchment Management Committee, which then reports on the Waikato river catchment progress to the full Waikato Regional Council.

5 Conclusion

The cooperative development of large constructed wetlands is a cost effective method for improving water quality. A constructed wetland is effective at mitigating contaminants from multiple properties and could be used by those properties as a means to meet their individual water quality targets.

The presence of positive externalities and the aspects of a public good that a wetland possesses means that there is an incentive to free ride. Hence any successful cooperatively developed large wetland needs to have mechanisms in place to ensure that any enterprises who do not contribute to the costs of the wetland can be excluded from receiving the benefits of the wetland.

The primary incentive for enterprises in a subcatchment to develop the wetland is that by pooling their resources they can achieve more water quality improvement at a lower cost than individual mitigations on their own properties.

This research report used the IAD framework, Ostrom's principles, economic concepts and feedback from interviewees to analyse what a pathway to achieving a cooperative wetland solution might look like. Initially, identifying the desired outcome of cost-effective water quality improvement is important to ensure that all participants in the wetland scheme are working towards the same objective. Secondly, a pre-feasibility study (including a broad level cost-benefit analysis) is required to estimate whether or not a wetland is a viable mitigation option for a particular subcatchment. The next step of the wetland development is forming the cooperative group. It is important that the actors in the local community are given time and space to develop their own ways of working and rules in use that will work for their particular situation. Then the cooperative group would need to decide on further specifications for the wetland and determine what level of mitigation they will build the wetland to and the resulting costs and benefits (including important co-benefits) that are associated. Once this is complete the discussion turns to who should pay the costs and receive the benefits. There are many factors to consider here, such as compensation for any land lost to the wetland, opportunities for offsets from point sources, external funding and any out-of-the-box ideas, such as harvestable food grown in the wetland. Lastly the group needs to finalise the agreement and to develop a monitoring and enforcement plan.

The cooperative development of large constructed wetlands has the potential to provide vast mitigation cost savings whilst also resulting in large scale water quality improvements. There are many scientific, social and economic challenges involved in this mitigation option. However, if the institutional conditions are set up right, and the will of the people to pursue this option is there, then there is no reason why cooperatively developed large constructed wetlands can't prove to be a major part of the solution to water quality issues.

Appendix 1 – Wetland efficacy, cost effectiveness and associated uncertainties

Wetland efficacy and cost effectiveness

Wetlands are generally regarded as an effective mitigation option for reducing discharges a variety of contaminants (Dordio, Carvalho, & Pinto, 2008; Moore, 2008; Kroger, 2008)

As part of the scenario modelling for the Healthy Rivers/Wai Ora process, Doole (2015) made assumptions regarding the cost and efficacy of a range of mitigation options. To do this Doole undertook a systematic review of reports on the efficacy of mitigation options, utilised expert opinion and ground-truthed the efficacy and cost assumptions with land owners. An extensive sensitivity analysis was also undertaken which showed that the estimates of relative cost and efficacy were very robust to changes in the values utilised. Hence even if the values used aren't exactly correct, they can still be relied upon to produce useful comparisons between mitigation options.

In the modelling wetlands were split between 'small wetlands' (1% of the catchment area) and 'medium wetlands' (2.5% of the catchment area). 'Medium wetland' mitigations were utilised extensively in the scenario models solution for the 80 year timeframe, indicating that they are a very cost-effective water quality solution. In the 80 year scenario, over 200,000 ha of land was being serviced by medium wetlands, out of a Waikato catchment that is approximately 1.1 million ha in total (Doole, Elliot, & McDonald, 2015b). It is also worth noting that a not insignificant amount of land to be serviced by 'medium wetlands' (around 42,000 ha) was suggested as being part of the most cost-effective solution in the first 10 years (Doole, Elliot, & McDonald, 2015b). Hence it is clear that wetlands are a key part of the water quality solution in the Waikato region.

Interview participants were in agreement that wetlands are generally effective at mitigating all four main contaminants for a low cost relative to other mitigations.

"Constructed wetlands are a very effective technology for removing contaminants at a relatively low price per unit" – **Sustainable Agriculture Advisor (Waikato Regional Council)**

Uncertainties regarding wetlands

Whilst the general efficacy of wetlands at mitigating water quality is well established, it is also well established that wetlands are very much 'horses for courses' in regards to a number of aspects of their function and design [Moore, 2008; Dordio, Carvalho, & Pinto, 2008).

Interview participants identified that wetlands can be (and should be) situational. This feedback was about both the design of the wetland and whether or not a wetland should even be a part of the subcatchment water quality solution. It is important that the analysis of whether or not to use a constructed wetland occurs upfront. Furthermore, each subcatchment will have a different topography, geology, water quality issues etc. Hence in order to be most effective each constructed wetland needs to be different and flexible depending on the local circumstances. A constructed wetland can't be the same product that is mass produced and rolled out, though naturally some elements will be similar between wetlands.

"The identification of suitability [regarding the use and design of wetlands] is key. It will be horses for courses" – **Associate Professor of Earth Sciences (University of Waikato)**

A wetland is a dynamic environment that changes through the seasons of the year and over time in general (Dordio, Carvalho, & Pinto, 2008). Change is inevitable with wetlands. The type of wetland, local climate, soil types, where the wetland is situated in the sub catchment, design aspects (such as flow paths), and the types of flora and fauna present are just some of the many features of wetlands that can affect their efficacy and mitigation potential (Dordio, Carvalho, & Pinto, 2008). Hence, the exact amount of contaminant mitigation from a wetland won't be the same year to year, though this is the case for a lot of mitigation options.

There are many questions to be asked when looking at what the best approach to the application of wetland mitigation to a subcatchment.

Firstly, would it be more efficient and effective to have a layered approach (with many small wetlands cascading down the catchment) or one larger wetland at the bottom of, or at a strategically placed interval in, the catchment? Both options have different positives associated with them. A cascading system of wetlands provides for a more even distribution of water quality improvement throughout a subcatchment as wetlands (Harrington, Carroll, Carty, Keohane, & Ryder, 2007). Furthermore each individual wetland can be designed to best deal with the particular local issues, e.g. if sediment is a particular problem in one tributary, the small wetland there could have aspects such as a sediment trap specifically designed into it. One larger wetland placed at a strategic point in the subcatchment has advantages in terms of overall efficacy and cost effectiveness. Larger wetlands have been shown to mitigate larger percentages of contaminants than smaller wetlands (Doole, 2015). There is also evidence that suggests that placing wetlands further down the catchment is more effective at removing contaminants than placing wetlands nearer the top of a catchment (Tanner, 2013). Furthermore, there would be some economies of scale advantages during the construction phase, e.g. only have to move the digger to one location.

For the larger wetland the burden of providing the land would fall only on one land holder, whereas under a layered approach the burden would be spread between many land owners. This is an equity consideration and land owners could be compensated by other land owners for their loss of productive land at a fair rate. For the purposes of this research paper, only the larger wetland option will be looked at, though it is highly likely that at least in some circumstances a layered approach may be more appropriate. This is one of the many questions that could be answered as part of the proposed pre-feasibility study (a concept to be discussed later in this research paper).

Another question regarding wetlands concerns their ability to be self-sustaining, maintained or even harvestable. A wetland is an expensive asset, and like any expensive asset, it is important to ensure that it is maintained properly in order to function at maximum effectiveness over a significant period of time. Depending on the design of a wetland system it may be more or less able to be self-sustaining, i.e. requiring little to no maintenance to function at peak effectiveness. This would depend on a number of factors such as the types of plants used, the presence of and propensity to incur weeds, and the amount of nutrients and sediments flowing into the wetland system (Alvarez & Becares, 2008). It may also be the case that useful plants for food or fibre could be incorporated into the wetland system, e.g. flax, watercress or even Manuka trees for bees and honey. Sediment and/or plant matter could also be harvested and redistributed to properties or sold as fertiliser (Moore, 2008). Hence it may be prudent to develop mechanisms to facilitate the easy maintenance of the wetland from the start, such as pathways to clear sediment traps and harvest/replant plant matter.

One more question to answer when designing a wetland is what will the interaction with ground water and water quantity in general be? Depending attributes of the location where the wetland is situated a wetland can give water to groundwater, receive water from groundwater or a combination at different times. This will impact the quantity of water in the wetland at a given time, the type of wetland it will be and therefore its effectiveness at mitigating contaminants (Moore, 2008). The quantity of surface water flowing in to a wetland is also important to know. Too little water and the wetland may dry up, too much water and the wetland may ‘blow out’ and get damaged. Hence the peak and trough flows are important to know when designing a wetland.

Many interviewees emphasised that there is a need to consider water quantity as well as quality when designing a large constructed wetland.

“Hydrology and flows are key things to keep in mind in regarding wetland design and efficacy” – **Associate Professor of Earth Sciences (University of Waikato)**

In particular it is important to consider what level of flood mitigation you are aiming to design the wetland too. Big floods can ‘blow out’ wetlands which would destroy the investment and potentially release the contaminants stored therein. However higher flows contain a larger proportion of the contaminants (particularly sediment and *E.coli*) that wetlands are aimed at mitigating, hence in order to be most effective a wetland should be designed to deal with as the highest level of flow possible, with a pathway to divert the flow should there be a risk of ‘blowing out’ the wetland.

This level of protection could be discussed and agreed upon by the cooperative group as there is an inherent trade-off, and diminishing marginal returns, between the amount of protection a wetland provides and the amount of money invested in it

Wetlands can be designed to be more or less effective in different weather conditions and can potentially play a role in flood protection if designed to do so, e.g. floodplain wetlands (Moore, 2008). However, as noted previously too much water can make wetlands ‘blow out’ and hence if the flows become too large it is important to ensure that there is an alternative path for water to flow (even if it is just the main stream channel). This is a consideration that councils and communities make already with their flood protection designs, e.g. designed to be able to handle a 1-in-50 year flood event.

Would it be more effective to have lots of smaller constructed wetlands than one large constructed wetland?

Some interviewees questioned whether or not it would be more effective to have a cascading approach, where there are multiple smaller wetlands scattered throughout the catchment, then one large constructed wetland towards the bottom of the catchment.

There is some evidence of this approach from Ireland (see Harrington et.al, 2007). Smaller wetlands would also have a positive impact on their local water quality which is an advantage over the one large wetland approach.

However it has been established that one large wetland is more efficient (more mitigation for less area and cost) at mitigating contaminants than smaller wetlands (see Tanner, 2013)

Hence it would be preferable to utilise one large wetlands for cost-effectiveness reasons, all other things being equal. Though this is something that should be fully explored as part of the proposed pre-feasibility study as a cascading approach may be required or desired in some situations.

Are wetlands net contributors of *E.coli*?

Some participants that questioned whether the presence of waterfowl in wetlands would lead to them being net contributors to *E.coli*. This view contradicts the outcome of the literature review (Doole, 2015) conducted as part of the scenario modelling reports which indicates that wetlands are highly effective at mitigating *E.coli*. This is further backed up by international research by Fleming & Fraser (2001) which involved another literature review of several studies which analysed the impacts of waterfowl on water quality. None of the studies involving wetlands indicated any significant increase in *E.coli* due to the presence of waterfowl[4]. Nevertheless there is a least one case in New Zealand in which *E.coli* has risen in a wetland likely due to the presence of birdlife (Groundtruth, 2015). Hence it is another aspect which needs to be looked at during the scientific investigation stage, when deciding whether or not to construct a wetland for improving water quality, particularly if the wetland is being built to mitigate *E.coli*.

Need to consider 'reverse land use change'

Another mitigation option that the model by Doole et al. (2015a; 2015b) highlighted is potentially going to be necessary in places is 'reverse land use change' or putting pasture into trees (either commercially or otherwise). Due to the nature of the model and the large financial impacts of 'reverse land use change' it instinctively makes sense that this mitigation option only occurs in the model when it is either the most cost effective option or there is no other option that would meet the water quality targets. Such a process may take place naturally as water quality targets become more severe but it is

[4] Interestingly some studies found increased N and P loadings at times in wetlands due to the presence of waterfowl, however this was only in winter and when bird populations were at their highest, i.e. 45,000 geese, due to migratory tendencies (the study was conducted in Canada). Such a situation is unlikely to occur in New Zealand due to differences in birdlife.

more likely, and more desirable, that a supported and directed pathway is set out to make the necessary land use changes.

Another option is that land users could group together, like they could for wetland development, to purchase and retire land further up the catchment as an offset if it is cheaper for them to do so after applying good management practice and exhausting other mitigation options on their properties.

Appendix 2 – Evaluative criteria

An important aspect that the analyst needs to consider when assessing potential outcomes is that of evaluative criteria. Evaluative criteria are used to compare against each other different institutional arrangements that could lead to a potentially successful outcome. Comparing institutional arrangements allows the analyst to understand which institutional arrangements are most likely to achieve the results that the community desires.

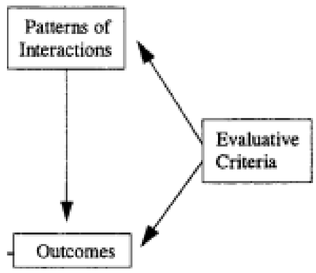


Figure 6 – The right hand side of the IAD framework. Source: Ostrom, Cox & Schlager (2014)

The most commonly used criteria in IAD studies are (1) economic efficiency, (2) equity through fiscal equivalence, (3) redistributional equity, (4) accountability, (5) conformance to general morality, and (6) adaptability (Ostrom, Cox, & Schlager, 2014). In addition to these criteria for the purposes of this study a further two criteria will be used, (7) efficacy for co-benefits, and (8) building social capital.

(1) Economic Efficiency. This criterion, in relation to cooperative wetland development, refers to the ability of institutional arrangements to achieve a given level of water quality improvement for the least amount of cost. One of the assumptions (assumption 2) for the purposes of this research is that a large cooperative wetland is at least part of the economically efficient solution to improving water quality in a given subcatchment. Hence this criterion would refer to the different institutional arrangements through which a cooperative wetland could be developed and would assess their relative merits in terms of achieving the water quality limits for the least amount of cost.

(2) Equity through fiscal equivalence. This criterion refers to the ratio between what an actor contributes to the building and maintaining the wetland and the benefits (or in most cases the reduced on farm mitigation costs) that they will derive from it. In general the concept of equity holds that those who benefit from a service should be responsible for paying for it; this relates to Ostrom's second principle of proportional equivalence between benefits and costs. Any deviation away from such an approach would risk affecting the willingness of actors, who have to pay more than their share, to contribute to the costs of developing and maintaining the wetland. However, improvements in water quality benefit a wide variety of private and public actors and hence any allocation of costs and benefits is inevitably going to be complex and will result in many possible 'equitable' allocations depending on the values of the actors involved. This research will look at both of the main perspectives, i.e. a 'right' to clean water and a 'right' to use land as seen fit by the land user. I will give extra weighting to options that can provide a pragmatic balance between these two extremes so that ideally, even if no one feels completely happy with the outcome, at least no one feels like they have been inequitably targeted.

(3) Redistributional equity. This criterion refers to an actor's ability to pay for their contribution to the costs of the wetland. In some cases one actor may choose to pay a proportion of

another actor's costs either in terms of a grant, a loan or an in-kind payment. They may receive some benefit for this or may simply do it out of the kindness of their heart.

(4) Accountability. In a democracy, governments and public officials should be accountable to citizens, particularly when natural resources and the public good is involved. This criterion will look at how well a given institutional arrangement allows for this accountability to occur.

(5) Conformance to general morality. This criterion refers to how well institutional arrangements deal with aspects such as free riding, gaming and keeping to agreements. The ability of actors to cheat and go undetected or the ability of an institutional arrangement to reward actors for keeping their word is an essential element that a successful cooperative solution will need to deal with in order to work in the long term.

(6) Adaptability. This criterion refers to the ability of an institutional arrangement to be altered in response to a changing environment. Natural resource management is situated in an ever-changing and complex world of variables. Any successful institutional arrangement will need to be able to be flexible enough to both changing environmental conditions and changes to the needs and wants of the actors.

(7) Efficacy for co-benefits. This criterion refers to the ability of the institutional arrangements to provide for benefits other than the primary benefit of improved water quality. Examples of co-benefits include: increased biodiversity, more recreational opportunities, potential for food sources, and potential for enhanced cultural wellbeing and access to the river.

(8) Building social capital. This criterion refers to the ability of institutional arrangements to increase social capital in the local subcatchment community. Social capital can be defined as "connections among individuals—social networks and the norms of reciprocity and trustworthiness that arise from them" (Putnam, 2000, p.19). Any cooperative solution has the potential to enhance social capital and institutional arrangements that can support this outcome are desirable.

As Ostrom, Cox and Schlager note "it is impossible to devise institutional arrangements that fully realize each evaluative criterion" (2014, p. 276). There will inevitably be trade-offs between these criteria. However, good institutional arrangements will consider each of these aspects and incorporate all of them to a maximum extent possible" (2014, p. 276). There will inevitably be trade-offs between these criteria. However, good institutional arrangements will consider each of these aspects and incorporate all of them to a maximum extent possible.

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