Setting Limits to Regulate Non-Point Source Pollution: a Comparative Study of New Zealand and the United States

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by

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Diffuse, or non-point source pollution, derives from a vast array of activities which involve no single distinct source thus making it difficult to manage with regulations. Efforts to do so have been gaining considerable momentum both internationally and in New Zealand. This research examines how approaches to regulate diffuse pollution differ between New Zealand and the United States, and what challenges these differences present for water quality policy implementation. It uses a comparative case study approach and focuses on the catchments of Te Waihora and Chesapeake Bay. Drawing on a conceptual framework that focuses on factors which influence policy implementation, this study highlights that although setting quantitative limits may appear ideal in theory, the complexity of diffuse pollution and the capacity of governments to regulate it make the implementation of resource limits very challenging.

Keywords: diffuse pollution, non-point source pollution, New Zealand, United States, Canterbury, Te Waihora, Chesapeake Bay, Delaware, agriculture, nutrient load limit, Total Maximum Daily Load

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List of Acronyms and Abbreviations

BMP = Best Management Practice

CAFO = Concentrated Animal Feed Operations

CWA = Clean Water Act 1972

CWMS = Canterbury Water Management Strategy

ECan = Environment Canterbury

GMP = Good Management Practice

LWRP = Land and Water Regional Plan [Canterbury]

NPSFM = National Policy Statement for Fresh Water Management 2011

RMA = Resource Management Act 1991

TMDL = Total Maximum Daily Load

WIP = Watershed Implementation Plan

ZIP = Zone Implementation Programme

1. Introduction

Although significant focus and regulations have been put in place to manage point source pollution for a number of decades, moves to regulate diffuse pollution have gained momentum internationally and in New Zealand only over more recent times. For example, in areas throughout Europe land restrictions and nutrient limits have been enforced, and in Scotland once voluntary good practice measures now have regulatory enforcement (European Commission, 2010; Hendry & Reeves, 2012).

Concern surrounding agricultural-sourced diffuse pollution is a contentious issue in New Zealand where there is pressure to both intensify agricultural production and minimise the environmental effects on the country's freshwater resources (Robson et al., 2012). The three freshwater pollutants that have been identified as providing the most concern for New Zealand water bodies are pathogens, sediment and nutrients such as nitrogen and phosphorus (Parliamentary Commissioner for the Environment, 2012). These pollutants may enter water bodies through either point source pollution or non-point source (diffuse) pollution. The diffuse or non-point source component is created from a vast array of activities which involve no single distinct source thus making it very difficult to regulate (National Institute of Water and Atmospheric Research, 2011). Hence, while there is broad agreement that diffuse sources are an important contribution to the diminishment of water quality, approaches to manage it differ considerably both within New Zealand and internationally.

In New Zealand the National Policy Statement for Freshwater Management 2011 (NPSFM) requires regional councils to set enforceable freshwater quality limits for all bodies of freshwater. The Canterbury Water Management Strategy (CWMS) also requires limit-setting. It establishes ten governance bodies known as zone committees across Canterbury. Under the NPSFM and CWMS, a catchment nutrient load limit for nitrogen has recently been established in the Selwyn/Waihora catchment (Environment Canterbury, 2011). A target for phosphorus concentration within Te Waihora/Lake Ellesmere has been established and included in the proposed Selwyn Waihora chapter of the Land and Water Regional Plan (Notified February 2014). Although no numeric catchment load limit has been established to meet this target, a suite of farm, catchment and lake interventions have been included in the solutions package in order to manage phosphorus (M. Robson, personal communication, February 26, 2014). A similar approach to deal with diffuse pollution, known as a Total Maximum Daily Load (TMDL) has existed in the United States under its Clean Water Act since 1972. However at that early stage it only dealt with point source pollution (Copeland, 2012). Since the mid-1990's TMDLs have gained increased importance in particular for seeking to manage non-point source discharges given their significant impacts on water quality, as well as a number of court cases leading to requirements to increase compliance with TMDLs (Hoornbeek, Hansen, Ringquist, & Carlson, 2013).

This research examines how approaches to regulate diffuse pollution differ between New Zealand and the United States, and what challenges these differences present for policy implementation and the achievement of water quality objectives. It compares limit setting in the catchments of Te Waihora, for which nutrient limits have recently been set through the Canterbury Water Management Strategy, and Chesapeake Bay, where a TMDL was established in 2010.

1.1 Research Aims and Objectives

The aim of this research is to compare limit setting approaches to regulate diffuse pollution in New Zealand and the United States.

The objective is to conduct a comparative study of the catchments of Te Waihora and Chesapeake Bay.

The research question that has guided this research is:

- How do approaches to regulate diffuse pollution differ between New Zealand and the United States, and what challenges do these present for policy implementation and the achievement of water quality objectives?

1.2 Outline of Dissertation

This dissertation is presented in nine chapters. Chapter One introduces the issues surrounding freshwater quality, particularly highlighting the issue of diffuse pollution. This chapter also introduces the purpose of this dissertation and specifies the research aims, objectives and focus question. The second chapter provides a background on water quality, the impacts of diffuse pollution, and a general background on the setting of limits on natural resources. Chapter Three describes the methodology for this research which adopts a comparative case study approach. This chapter also provides an introduction for the two case study locations. Chapter Four provides a conceptual framework for this research. The conceptual framework presents theoretical insights on the use of the power to regulate, the knowledge of limits, and what impacts collaboration can have for implementation in watershed management. Chapter Five focuses on the Te Waihora catchment case study, including the establishment of the limit setting process, its governance, power to regulate, knowledge of limits, and the degree to which collaboration was incorporated. Chapter Six directs these same components to the Chesapeake Bay catchment case. Chapter Seven, a cross case analysis, presents the findings of this research and sets out the similarities and differences that have been identified between the two case studies. Chapter Eight, the Discussion, applies the theory from the conceptual framework to the findings and discusses lessons learned from the two case studies to distinguish challenges for water quality policy implementation. The last chapter (Chapter Nine) provides conclusions to be taken from the research and suggests areas for further research.

2. Background

2.1 Water Quality and Diffuse Pollution

With issues such as global warming, human population growth and increasing food demand, there is a greater stress on global freshwater resources, particularly regarding the quality of these freshwater resources (Hoornbeek et al., 2013). In New Zealand these pressures have a long history. For example, the surge in New Zealand's economy after the Second World War resulted in increased pollution from factories, farms and urban settlements (Parliamentary Commissioner for the Environment, 2012). More recently, the intensification of agricultural practices (amongst other factors) has placed pressure on water quality. In Canterbury, the seemingly abundant groundwater resource has led to an increase in dairy farming. Approximately 60,000 ha of land is now irrigated by groundwater in Canterbury predominantly for this land use (Environment Canterbury, 2011c). A rise in the conversion of land use to dairy farming (amongst other factors) has led to a rapid increase in the application of nutrients to land across Canterbury. This intensification of land use has led to concerns that excess nutrients are entering and polluting waterways (Parliamentary Commissioner for the Environment, 2013).

Diffuse pollution is defined as pollution that is not discharged at a single point but rather from multiple indirect points to surface water through land runoff, seepage and drainage (Copeland, 2012). Diffuse pollution can arise from a range of sources. In a rural setting, agricultural and forestry activities can result in diffuse pollution, leading to impacts such as increased acidification and nutrient release (D'Arcy & Frost, 2001). In an urban setting, stormwater runoff is a significant issue, with contaminants such as oil, toxic metals and nutrients making their way into local water bodies (Campbell, D'Arcy, Frost, Novotny, & Sansom, 2004). It is widely accepted that diffuse pollution from urban and rural sources contributes significantly to the degradation of water bodies; however, it has often been much harder to control diffuse pollution because of its unwieldy nature (Copeland, 2012).

Point source discharges are generally more easily controlled, with most countries issuing a discharge permit or consent which is subject to various conditions. The volume of discharge associated with a point source is usually well-known and therefore can be easily regulated (D'Arcy & Frost, 2001). Diffuse pollution is much harder to control as the discharges are often intermittent, from multiple sources resulting in cumulative effects, highly variable, the timing of discharges is difficult to predict, and it is also difficult to sample diffuse pollution discharges. These factors can make it difficult to apply normal consents or permits for diffuse pollution and therefore often other measures will need to be found (Freeman, 2012). The lag-effects of diffuse pollution in groundwater are another issue and can mean that the full impact of diffuse pollution on water bodies may not be accounted for in the present. This is because some diffuse pollution sources such as nitrogen applications to land can spend a significant number of years moving through groundwater before reaching surface water (Environment Canterbury, 2013b). This means that even if mitigation is occurring, water quality may deteriorate or remain polluted before it improves. Similarly, the impacts of reducing nutrients to land may take a significant time period for positive water quality impacts to be noticed.

2.2 Sources of Pollutants and their Ecological Effects

Both Chesapeake Bay and Te Waihora have been identified as having high nitrate and phosphorus concentrations, and for the purpose of this research these two pollutants are examined (Copeland, 2012; Environment Canterbury, 2013b).

Both nitrogen and phosphorus perform many key biological functions. Both nutrients are essential to all life, particularly for plant growth (Parliamentary Commissioner for the Environment, 2013). Nitrogen (N) and phosphorus (P) are applied to soil through sources such as animal manure, fertiliser applications, wastewater discharges, and stormwater carrying pet waste and detergents. Once nitrogen is applied to the soil a significant amount is used by plants. However, this nitrogen can also follow a number of other paths. As shown in Figure 1 not all nitrogen is taken up by plants, and it can either run off into surface water bodies or can be leached into groundwater. The majority of N that is leached through agricultural soils is in the form of NO_3 and NH_4-N, and undertakes the process of mineralisation with the conversion of organic nitrogen to ammonium. Often this will leach into groundwater where it will eventually reach surface water through springs. Notably though not all nitrogen that reaches groundwater will make its way to surface water. The process of denitrification converts nitrate (NO_3^-) to gaseous forms of N, either a greenhouse gas or an inert gas (Stenger et al., 2013). This process reduces the the quantity of nitrate present in groundwater systems before it enters surface water bodies (Stenger et al., 2013). Surface runoff can also result in nitrogen reaching surface water bodies when precipitation is greater than the infiltration capacity of a soil. This form of nitrogen loss is highly dependent on catchment characterisitcs such as annual rainfall, topography, soil cover, and land use (Parliamentary Commissioner for the Environment, 2013).

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The majority of phosphorus in the environment is stored in sediment and rock where it is strongly bound to soil particles. Thus as well as animal effluent and fertilser applications being main contributors of phosphorus to water, the erosion of rock and soil to waterways is another significant contribtuor of phosphorus. Phosphorus has a tendency to build up in lake bed sediments. If phosphorus remains locked up in the sediments, it is not usually available for use by plants. However, a number of processes can result in this phosphorus being released back into the water. Such processes can include bottom-dwelling aquatic organisms stirring up the sediments, or high winds creating the stirring up of such sediments (Minnesota Pollution Control Agency, 2008).

Water bodies do require a certain level of nutrients to be healthy, however, what is problematic from a water quality perspective is that excess nutrient levels can lead to the growth of unwanted plants and algae such as periphyton and cyanobacteria. Excessive growth of such plants can cause the release of toxins and clog waterways. When nutrient levels are exceedingly high they also have the ability to directly impact freshwater life, leading to impacts such as fish kills (Ministry for the Environment, 2013). This is due to the decomposition of the excess plant growth by bacteria which in turn can reduce dissolved oxygen levels in a waterbody thus suffocating fish and other aquatic life (Minnesota Pollution Control Agency, 2008).

The effects of excess nutrients in surface water and groundwater can also pose a threat to human health if there is contact with or ingestion of the water. In Canterbury, drinking water supplies are sourced from groundwater with none to little treatment. This means excess nutrient levels can pose threats to humans with the potential for issues such as blue baby syndrome (methemoglobinemia) (Brown, 2010). The polluted water can also have detrimental impacts on animals such as dogs if they make contact with a toxic blue-green algae termed *Phormidium* (Brown, 2010). In New Zealand, the Maximum Allowable Value for Nitrate-Nitrogen in drinking water is 11.3 mg/L (Environment Canterbury, 2012e).

2.3 Setting Limits on Natural Resources

Diffuse pollution is cumulative in nature, with every land use potentially being a source of diffuse pollution (Mandelker, 1989). Cumulative effects are defined as those effects which arise over time or that occur in combination with other effects. Case law in New Zealand has found that cumulative effects can also include "additive effects of other possible but not yet occurring permitted activities and the effects of granted but not yet implemented consents" (Green, 2013, p. 155).

The primary environmental legislation in New Zealand – the Resource Management Act 1991 – is viewed as managing the effects of individual activities. However, Green (2013) states that cumulative effects are not well managed, particularly those associated with pastoral farming. Green (2013) maintains that the management of cumulative effects requires a catchment-wide approach. Justice Salmon (2007) argues that the best framework to manage cumulative effects under the RMA would be to identify the relevant resource and determine its capacity, and then to limit the resource use appropriately. It is a recurring theme that limits are the only effective means by which to manage cumulative effects, such as the setting of quota limits on fish stocks (Green, 2013). Setting limits on resources recognises that these resources "in terms of both quantity and quality, have a finite capacity-for-use beyond which further use is unsustainable without resulting in harmful effects on the environment, values and other uses of the resource" (Robson et al., 2012, p. 2).

2.4 Summary

This chapter highlights that increasing pressures are being placed on freshwater resources and that diffuse pollution is a large contributor to this. Nitrogen and phosphorus are two of the main pollutants for both Te Waihora and Chesapeake Bay, and although they hold key functions for all life, in waterways excessive quantities can lead to the release of toxins and cause pollution. The setting of limits on natural resources has been identified as one way to control cumulative effects, with diffuse pollution being cumulative in nature. The following chapter examines the theory around a number of aspects which impact policy implementation of these limits.

3. Methodology

This research compares how approaches to regulate diffuse pollution differ between New Zealand and the Unites States. It has adopted a comparative case study approach by way of setting limits in the Te Waihora catchment of Canterbury, New Zealand, and the Chesapeake Bay catchment in the United States.

It is understood that these case studies are not representative of New Zealand and the United States, and that other comparisons could have been chosen. However, there are a number of justifications for choosing these two case studies. The Te Waihora catchment has been chosen in New Zealand as a package for diffuse pollution management measures has been recently intitiated and involves the setting of a catchment nutrient load limit for Nitrogen. The limit setting approach that is being used for Canterbury has provided an approach that has been adopted by central government for further water reform management beyond that of the NPSFM 2011 (Duncan, 2013b). Chesapeake Bay has been chosen for the United States case study for numerous reasons. The Total Maximum Daily Load (similar to the package initiated in New Zealand) for Chesapeake Bay is the largest in the US, and just as national attention was given to Te Waihora/Lake Ellesmere for a clean up in 2011 (Williams, 2011), President Obama declared Chesapeake Bay a “national treasure” and ordered the federal government to take a leadership role in restoring Chesapeake Bay in 2009 (Copeland, 2012). A summary of the similar characterisitcs of the two catchments is also provided at the end of this chapter following the introduction of both case studies.

A key characterisitc of case study research is its tendency to focus on the ‘how’ and ‘why’ (Yin, 2009). Focusing on the ‘how’ and ‘why’ means that the case study method is best suited for in depth research, and also because case study research is a detailed research method (Cassell & Symon, 2005; Yin, 2009). Examining the two case studies of Chesapeake Bay and Te Waihora allows a comparative analysis to be undetaken to examine the differences both within and between the cases (Baxter & Jax, 2008).

Case study research can be subject to a number of criticisms. One such criticism is that it cannot provide a generalising conclusion, as it only focuses on one or a small number of cases (Tellis, 1997a, 1997b). However, Yin (2009) and Hamel, Dufour, & Frotin (1993), argue that analytic generalisations can be undertaken with the use of previously developed theory (in this research a conceptual framework) which can be used to compare against the empirical results of the case study. Additionally, case study research has been viewed as microscopic as it lacks a sufficient number of cases (Tellis, 1997b, p. 3). However, this claim has been disputed with some saying that whether the relative size of the sample includes few or many cases, it will not transform it to a macroscopic research method, and even a single case is acceptable so long as it meets the established objective (Tellis, 1997b, p. 3).

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Figure 2 outlines the steps involved in comparative case study research. Initially, the 'define and design' step of the research involves the selection of cases and development of theory. The decision to examine Te Waihora and Chesapeake Bay has been outlined throughout this chapter, and the theory was developed to construct a conceptual framework. This conceptual framework serves as the anchor to this research (Tellis, 1997b). For the conceptual framework academic journals were drawn upon to establish the theory that was required. Information for the two case studies was then collected and examined to write up an individual report for each case study (Chapters Five and Six). The analysis and conclusion step involves drawing cross-case conclusions (Chapter Seven), and throughout the research the theory in the conceptual framework was constantly updated to reflect the different ideas and themes that emerged with research. This theory was then utilised for the comparative case study report (Chapter Eight).

Chesapeake Bay – the case study for the United States is made up of seven jurisdictions. For this reason the Chesapeake Bay case study has focused on the specific jurisdiction of Delaware when increased detail was required. Delaware has been chosen as it was possible to have informal discussions with individuals from Delaware University who could provide information relevant to the TMDL implemented by the State of Delaware.

3.1 Data Collection Methods

Yin (2009) has stated that case study research relies on the use of a number of sources of evidence. For this reason this research has undertaken a document analysis. This required the review of a range of sources including publicly available reports, government documents, websites, newsletters, academic journals, and relevant media releases.

Another form of information that was drawn on was through the use of informal discussions. These discussions were open-ended and were held with the three people listed below. The respondents provided insight into the events of both limit-setting processes, and were able to provide information specific to each case study. The use of discussions has been identified as one of the most important sources for case study information (Yin, 2009).

- Dr. Tom Sims – Deputy Dean and Professor (University of Delaware - College of Agriculture & Natural Resources)
- Jennifer Volk – Environmental Quality and Management Extension Specialist (University of Delaware - College of Agriculture & Natural Resources)
- Dr. Melissa Robson – New Zealand (AgResearch)

3.2 Introduction to Case Studies

3.2.1 Te Waihora and its Catchment

Te Waihora, also known as Lake Ellesmere, and its catchment area are located in the central Canterbury area of the South Island, New Zealand (refer to Figure 3). Te Waihora is a lowland coastal lake situated on the eastern boundary of the catchment. It is New Zealand's fifth largest lake, with an approximate area of 20,000 ha, and an average depth of 1.4 metres (Hughey & Taylor, 2009). The brackish nature of the lake is a result of its close proximity to the Pacific Ocean. Waves will often overtop the gravel bar of Kaitorete Spit, and the artificial periodic channel openings of the lake to the ocean allow inflow of sea water. This saltwater component of the lake is important for habitat and biotic biodiversity, with salinity levels in the lake varying both spatially and temporarily (Robinson & Davie, 2013). The Lake was claimed to be New Zealand's most polluted lake after NIWA's 2010 Water Quality Report compared trophic levels of 140 New Zealand lakes and Te Waihora came up with the highest trophic level index (TLI) of 6.9 (Smith, 2011). The current average annual TLI for the middle of the Te Waihora remains similar to this level at a figure of 6.8 (Environment Canterbury, 2013b).

The catchment area of Te Waihora includes a vast array of geographical features and has a land area of 276,000 ha (Hughey, Johnston & Lomax, 2013). Figure 3 shows the extent of the catchment area, which is made up of a foothill and lowland rural area – part of the Canterbury Plains which are made up of merging fluvio-glacial fans built up by the main rivers. The catchment includes hill fed rivers, groundwater zones, spring-fed streams and of course Te Waihora (Environment Canterbury, 2011c). The surface water from these tributaries is mainly sourced from groundwater within the catchment which has been derived from rainfall recharge and river seepage (Robinson & Davie, 2009).

The climate and rainfall of the Te Waihora catchment varies from the coastal boundary in the east to the foothills in the west. The Plains are characterised with low rainfall and a large annual temperature range. However, this rainfall average increases at the western extent of the catchment with the high country receiving significant rainfall and winter snow (Ryan, 1987).

The Te Waihora catchment is home to 42,000 residents, made up of a number of more densely populated towns such as Rolleston and Lincoln, and a number of the residents who reside on rural and lifestyle properties (Environment Canterbury , 2011c). The catchment is encompassed within a single regional authority – Canterbury Regional Council (Environment Canterbury). Te Waihora and its catchment have a range of cultural and economic values. These include, but are not limited to, agriculture, commercial fishing, recreation, mahinga kai, as well as supporting Ngai Tahu cultural values (Hughey & Taylor, 2009). The commercial fishery supplies to both domestic and international markets, and includes species such as eel, flounder and yelloweye mullet (Environment Canterbury, 2012g).

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Te Waihora catchment has experienced some major land use changes over the past 20 years. The seemingly abundant groundwater supplies in the Canterbury Plains have transformed a significant proportion of the landscape to green pastures for dairy farming. These land use changes reflect the response to market changes and demand, with the dairy sector becoming the highest earner of export dollars. The total land cover of the catchment is comprised of the following: 51 percent dry stock farming, 21 percent dairy farming, 14 percent cropping and horticulture, 6 percent forestry, and the remainder split between contract grazing, lifestyle blocks, and 'other land' (Hughey et al., 2013, p. 12). Freshwater resources in Canterbury are looked upon as being relatively abundant, particularly the groundwater resource. This has led to a signifcant increase in dairy farming in this region with 60,000 ha of land now irrigated by groundwater predominantly for this land use (Environment Canterbury, 2011c). A rise in the conversion of land use to dairy (amongst other factors) has led to a rapid increase in the application of nutrients to land across the Canterbury region.

3.2.2 Chesapeake Bay and its Catchment

Chesapeake Bay is the largest estuarine system in the United States, and includes a semi-enclosed body of water which is linked to the open sea (refer to Figure 4) (US Environmental Protection Agency, 2010). Chesapeake Bay is located on the eastern side of the US and is fed by 50 major tributaries, however, over 100,000 streams and rivers feed the Bay (Chesapeake Bay Program, 2012). The five largest rivers feeding the Bay are the Susquehanna, Potomac, Rappahannock, York and James (Chesapeake Bay Program, 2012).

Chesapeake Bay is brackish, with 50% of the water in the estuary consisting of freshwater from tributaries, and 50% made up of saltwater entering the bay through tidal movements. The twice daily rise and fall of the tide in Chesapeake Bay means the Bay has a reasonable chance to flush itself of pollutants. The saline water and freshwater more of present in the Bay are not evenly dispersed throughout the estuary, with freshwater quantities significantly higher nearer tributary mouths (Chesapeake Bay Program, 2012a). The average depth of Chesapeake Bay is 6.4m, making it a relatively shallow water body (US Environmental Protection Agency, 2010).

The Chesapeake Bay catchment covers an impressive 16,575,924 ha, and includes the District of Columbia, and sections of six states; Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia (US Environmental Protection Agency, 2010). The topography and climate of the catchment is variable with hilly and mountainous terrain and a colder climate in the north-eastern states, to flatter and warmer coastal plains in the mid-Atlantic (Sims & Volk, 2013). This large catchment area means the land:water ratio is the highest for any riverine estuary in the world (Sims & Coale, 2002). This high proportion of land area stresses the potential impact that diffuse pollution can have on the Bay. The Chesapeake Bay catchment area consists of a number of land use types: 58 percent forest cover, 23 percent agricultural land, 9 percent developed, and 10 percent is mixed open land. Although agriculture does not have the highest land cover percentage, it does contribute the largest portion of nutrients to the Bay. Crop production and animal operations are estimated to contribute 38 percent and 45 percent of the total nitrogen and phosphorus loads, respectively (Savage & Ribaudo, 2013; US Environmental Protection Agency, 2010). The increased development of urban cities and suburbs in the last 20 – 30 years has also led to increased stormwater runoff as a result of the increased impervious surfaces (Sims & Volk, 2013).

Pollution in Chesapeake Bay has without a doubt existed for hundreds of years. However, post-Second World War, pollution levels have drastically increased due to an increase in urbanisation, rapid population growth, agricultural development, as well as wetland loss as a result of these factors (Sims & Coale, 2002). The latest report card that has been issued for Chesapeake Bay, ranks a range of indicators and has scored the Bay 32 out of 100. This equates to a D+, and therefore the overall health of the Bay is classified as ‘poor’. This report was issued in early 2013 (Chesapeake Bay Foundation, 2013a).

Chesapeake Bay has provided economic and recreational benefits for many generations. The Bay has been popular for recreational fishing, hunting and boating, and provides significant economic benefit with a high annual seafood harvest of more than 500 million pounds each year (Maryland State Archives, n.d.). It is home to more than 3,000 bird species (both migratory and resident), and to 3,700 plant and animal species (Sims & Volk, 2013). Just as agriculture is seen as an important component in Te Waihora, agriculture in Chesapeake Bay is seen in a similar light where it is widely appreciated that it is a key part of the Bay’s history, culture and economy (Sims & Volk, 2013).

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The Chesapeake Bay watershed is now home to more than 17 million residents, which is a stark contrast to the Te Waihora population of 42,000 residents (Chesapeake Bay Foundation, n.d.). Most waters in the large catchment area of Chesapeake Bay are classified as impaired due to the large quantities of nitrogen, phosphorous and sediment inputs. In the Bay these pollutants are causing algae blooms which are killing shellfish and fish that cannot survive with the lack of oxygen caused by the decomposing algae. The algae blooms also block sunlight which is required for the underwater Bay grasses, and smother bottom dwelling aquatic life (US Environmental Protection Agency, 2010).

3.2.2.1 Summary of the Similarities of both Case Studies

The previous introductions for both case studies show that a number of similarities exist between the two case studies, as listed below:

- Significant land:water ratio
- Water body in context is located at the “bottom” of the catchment
- Agriculture is the main contributor of Nitrogen and Phosphorus within the catchment
- Economic values: agriculture, fisheries
- Extensive and significant bird life
- Brackish nature of the water bodies

3.2.2.2 Limitations of the Comparison

The comparison between Chesapeake Bay and Te Waihora raises a number of limitations. Firstly, the use of specific examples from Delaware for the Chesapeake Bay case study is not representative of the whole catchment. For example Delaware may have certain policies relevant to the implementation of the TMDL which other states do not. It is therefore important to understand that other states within the Chesapeake Bay catchment may not all be undertaking the same approaches as Delaware.

Another limitation of this comparison is that for the Te Waihora case study the limits have not yet been legally enforced, thus they may be subject to change. This has also meant that there is less information available surrounding the limit setting compared to the Chesapeake Bay case study, where the nutrient limit setting is more established.

4. Conceptual Framework

The following conceptual framework presents theoretical insights on the use of the power to regulate, the knowledge of limits, and what impacts collaboration can have for implementation in watershed management. The term implementation refers to taking action, and in environmental management refers to the implementation of policy. Implementation involves a move from "normative" planning (what should be done) to "operational planning" (what will be done). This shift in planning can prove to be challenging as there are often a number of obstacles for implementation (Mitchell, 2011). The difficulties experienced with a shift from normative to operational planning are particularly apparent for diffuse pollution. The characteristics of diffuse pollution including its cumulative nature make its management profoundly difficult.

4.1 The Power to Regulate Diffuse Pollution

When looking to achieve environmental protection, policymakers have the choice (amongst others such as market based approaches) between using a voluntary approach or a mandatory approach. Both of these approaches have benefits and consequences. The key difference that a mandatory approach has compared to a voluntary approach is identified by Alberini and Segerson (2002, p.157) as "the ability to impose unwanted costs on polluters".

For decades diffuse pollution has predominantly been enforced through voluntary measures due to the difficulty in regulating such an unwieldy pollution source. A lack of results in terms of water quality improvement has highlighted a link between a lack of regulatory enforcement and a lack of significant improvements in water quality. Perez (2011) highlights this point and states that if farmers are not required to implement nutrient management plans they are often less likely to. As the impacts of diffuse pollution often occur 'off-farm' they can seem to be 'invisible' to land users (Blackstock, Ingram, Burton, Brown, & Slee, 2010, p. 5632). Such characteristics can make communicating the importance of reducing non-point source discharges to land-owners particularly difficult. Previous examples of this have surfaced with Blackstock et al. (2010) stating that an evaluation of the uptake of agri-environmental schemes showed that famers had not been persuaded to change their behaviour due to the invisible and off-farm characteristics of diffuse pollution. Without the use of a mandatory approach this can make the implementation of limits more difficult. Thus a shift towards the regulation of diffuse pollution is occurring.

Voluntary approaches to environmental protection can take on three forms, including a unilateral action by a single polluter/group of polluters, a bilateral agreement between a regulator body and a polluter/group of polluters, and a voluntary government program. The voluntary government program, whereby the regulatory body alone defines both the rewards and requirements for participation is most likened to that used for nutrient limit setting in these case studies (Alberini & Segerson, 2002). The use of this and other types of voluntary programs have significantly increased over the last two decades and they include a number of benefits. A voluntary approach will often provide polluters with increased discretion as to which abatement strategies they choose to use at a minimum cost. This can result in cost savings compared to mandatory approaches which tend to dictate abatement strategies that may not always be the most cost efficient. Voluntary approaches can also be effective as they can initiate improved cooperation between polluters and regulators which can lead to increased information flows and effectively decrease implementation lags (Alberini & Segerson, 2002). However, voluntary approaches are also fraught with a number of weaknesses. Significant concern surrounds the ability of voluntary approaches to adequately provide environmental protection as polluters are not forced to provide environmental protection beyond what they deem sufficient. Criticism also exists with the concern that a focus on voluntary approaches shifts the focus from the 'worst' polluters to those who are most willing to reduce environmental impacts voluntarily (Alberini & Segerson, 2002).

A means of increasing the success of voluntary approaches which has been identified by Lubell (2004), is placing a threat of regulatory measures if voluntary approaches are not adopted. This provides an incentive for land owners to seek regulatory relief. "All over the country [US], in many different environmental policy arenas, the hammer of future regulation is an important motivation for current collaboration" (Lubell, 2004, p. 344). Another key technique for increasing the success of a voluntary approach is through providing financial incentives. "Economic viability is a central concern of the agricultural community. Farmers tend to resist any type of government policy that they believe will increase their production costs, and they are more likely to accept government policies that provide financial incentives" (Lubell, 2004, p. 344).

4.2 The Knowledge of Limits

In the last two decades the focus of prevention has become one of the most significant goals in environmental policy (Wynne, 1992). Although a preventive approach does bring a number of benefits, it does present many challenges. The use of a preventive approach relies heavily on "anticipatory knowledge" which carries limitations (Wynne, 1992, p. 111). One such limitation is the difficulty in defining 'what is an adequate level of investment in technological or social change to prevent environmental harm' (Wynne, 1992, p. 111). This is due to the requirement to make predictions about unknowable futures. Instead of the focus being placed at the end-of-pipe – as it often is with known point-source discharges – the focus is instead shifted to the upstream processes (Wynne, 1992). An upstream focus means that understanding and predicting discharge levels is more difficult than dealing with known discharges in a real-time, end-of-pipe situation (Wynne, 1992). The assessment of environmental impacts tends to have a significant focus on a preventive approach.

The precautionary principle has had a predominant presence in environmental regulation since it was endorsed by the German government in 1987 for the protection of the North Sea from global warming and pollution, prior to any causal link providing clear scientific evidence of these pollution issues. The precautionary principle has been supported by a number of environmentalists to deal with the issue of scientific uncertainty (Bodansky, 1991). The precautionary principle is based on the idea that instead of awaiting certainty, measures should be put in place in anticipation of environmental damage to ensure this damage does not occur (Bodansky, 1991). The implementation of the precautionary principle involves applying appropriate legal and economic bounds for action and reiterating the need for action despite the presence of scientific uncertainty (von Moltke, 1996). The acceptance of the precautionary principle poses a number of issues for implementation. One criticism is that the precautionary principle is based on the acceptance of suspicion rather than scientific evidence (von Moltke, 1996).

The National Policy Statement for Freshwater Management (2011) highlights that enforceable limits are a key step to achieving environmental outcomes (New Zealand Government, 2011), and Robson et al. (2012) has stated that limits are key to managing cumulative effects. The means of determining these limits is with predictive modelling. von Moltke (1996) maintains that no other area of public policy is as dependent on science and modelling as environmental policy.

Although models can provide valuable predictions for multiple scenarios, all models and assessment tools are subject to some degree of uncertainty. This uncertainty has a number of sources. Models may be run on sparse data which is not sufficient to reflect the complexity of the model or reality (Heathwaite, 2003). Trying to recreate and account for all the processes occurring within a natural environment for the purpose of a model is an impossible task. Natural ecological systems are a complex accumulation of physical, chemical and biological processes. Many of these processes are often non-linear and uncertainties exist in their interactions (Heathwaite, 2003). Although this uncertainty is often unavoidable, it is important that the uncertainty is recognised, acknowledged, and disclosed to the community (Robson et al., 2012). This is particularly important as setting limits on natural resources is a complex scientific problem. This means the information is often highly disputed making it increasingly difficult to "gain consensus and change behaviour" (Hendry & Reeves, 2012, p. 11). Ludwig, Hilborn, and Walter (1993) have stressed that effective policies are possible despite uncertainty, but it is important that uncertainty is taken into account.

A lack of transparency is another factor that can reduce the credibility of modelling. The data inputs of models are often unattainable or at very least difficult to obtain (Duncan, 2008). The careful choice and transparency of these inputs is important as models are highly dependent on inputs. Tennoy, Kvaerner, & Gjerstad (2006) explain that quite different results can be obtained if other input data and assumptions are chosen. Snelder et al. (2013) have also highlighted the importance of transparency, stating that water resource use limits are likely to be more readily accepted by stakeholders when the limits are set in a transparent process.

The complexity and level of input information into models is continually increasing as new discoveries are made in science and increased monitoring creates more detailed data sets (Duncan, 2013b). The Ministry for the Environment (2011) highlights that limit-setting is therefore not a static process; rather it will often require modification and fine-tuning once further and improved information is attained. This requires an adaptive management approach. Adaptive management is a process of learning by doing where monitoring and feedback loops allow for adjustment and to improve future management. It is also seen as particularly useful in situations where high levels of uncertainty prevail (Margerum, 2011; Stankey, Clark, & Bormann, 2005). Although in theory the idea of adaptive management is viewed as desirable, it poses a number of issues for implementation.

There are calls for the increased use of science and technology when predicting the effects of utilising natural resources and its resultant impacts such as that of climate change. However, these calls are balanced with those that claim the use of science and technology and decision making need to incorporate and better balance economic, cultural, and social needs (Cash et al., 2006). Research and practice have suggested that scientific information is likely to be more effective for use in decision making when stakeholders perceive the scientific information to be credible, salient and legitimate (Cash et al., 2006). Maintaining a balance between these levels of salience, credibility and legitimacy is difficult but important.

4.3 Collaboration in Water Management

Over the past century the topic of water quality has often been managed by individual, single-function governmental agencies that provide their own exclusive legal directions. Due to this, Sabatier et al. (2005) has claimed that decision making has often taken on a technocratic approach. This means that decisions have been made predominantly by technical experts and hence stakeholder involvement has been significantly limited to approaches such as public hearings and comment periods which are associated more with the ‘fine-tuning’ of the relevant proposals.

However, over the last 20 – 30 years this approach has been subjected to substantial criticism. This is partly due to the complexity and conflict that is associated with freshwater pollution control policymaking. It is also partly due to the dissatisfaction experienced by many with leaving a large proportion of policy decisions with government experts who may lack local knowledge (Sabatier et al., 2005).

A collaborative approach to water management is stated by its proponents as a process which provides mutual understanding and trust among stakeholders (Sabatier et al., 2005). A collaborative process will often have the support (or acquiescence) of stakeholders, which means that implementation will be less challenging than an approach taken that lacks a collaborative process (Sabatier et al., 2005). A collaborative approach is said to provide greater legitimacy as it involves stakeholders and will usually operate under a form of consensus rule. Lubell (2004) argues that for collaborative watershed management to be successful it must include cooperation from grassroots stakeholders. Lubell (2004) and Blackstock et al. (2010) highlight that it is the resource decisions of these grassroots stakeholders that cause the environmental issues. Thus it is vital to take into consideration the view of these grassroots stakeholders as it is ultimately the behaviour of these groups that is required to change.

4.4 Summary

The setting of nutrient limits has seen an increased shift to a mandatory approach over recent years. Mandatory approaches lack some of the characteristics that voluntary approaches hold such as increased discretion by the polluter and improved cooperation between polluters and regulators. However, voluntary measures may not provide sufficient environmental protection that mandatory approaches can unless monetary or regulatory incentives are incorporated.

The use of a preventive approach and hence predictive modelling is a key tool for determining limits on natural resources. These models can aid in providing estimations for nutrient load limits, but predicting complex processes of natural environments through simplifications raises issues of transparency and credibility. With the scientific complexity that is involved with limit setting, the evidence and predictions are likely to be highly disputed, making implementation and required changes of behaviour very challenging for regulatory authorities.

A collaborative approach to water management has increased in recent times and is likely to result in increased success of implementation of outcomes arising from collaboration. This is because it increases transparency and understanding with stakeholders, which is important as it is the stakeholders whose behaviour it is most important to change.

This conceptual framework has examined a range of issues associated with regulating diffuse pollution and the challenges they provide for implementation. These issues may create difficulties regarding the credibility, legitimacy and saliency of nutrient limits which are all important elements for increasing the success of implementation. This conceptual framework will be used to conduct a cross case analysis, as well as in the discussion section to provide theory regarding the findings.

5. Limit Setting for Te Waihora

This chapter examines the case study of Te Waihora. The following chapter examines the Chesapeake Bay case study. A range of aspects could be examined for both case studies, however, the following aspects have been chosen as they have implications for implementation which is analysed in the Discussion chapter. For both case studies an overview of the limit setting process and the numeric limits which have been set are provided for context. Governance, the power to regulate diffuse pollution, the knowledge of limits, and the scale of collaboration are examined for both case studies. A comparative chapter (cross-case analysis) follows the case study chapters which compares the aspects that have been described above for both case studies.

5.1 Governance

The Resource Management Act 1991 (RMA) is the overarching environmental legislation in New Zealand. Under the RMA is a hierarchy of planning tools. One of these tools is termed a National Policy Statement which empowers central government to prescribe policies on resource management issues of national significance (Environmental Defence Society, n.d.). In 2011, the National Policy Statement for Freshwater Management 2011 (NPSFM) was gazetted as part of the initial foundation for creating a "more efficient and effective freshwater management system" (New Zealand Government, 2011). The NPSFM highlights the importance of freshwater resources in New Zealand. The need for limits has increased as the demand for land uses that impact water quality have also increased, especially over the last 20 years (Robson et al., 2012). The purpose of the NPSFM is to provide a clearer central government policy direction to local government for achieving freshwater resource related goals, and to set enforceable limits on water quality and water quantity (Ministry for the Environment, n.d.).

One of the objectives of the NPSFM is that the overall quality of freshwater within a region be maintained or improved. To achieve this objective, the NPSFM states that every regional council making or changing regional plans needs to ensure the plans create freshwater objectives and set freshwater quality limits for all bodies of freshwater in their region (New Zealand Government, 2011).

The Canterbury Water Management Strategy (CWMS) which was initiated in 2009 prior to the NPSFM also sought to set limits (Environment Canterbury, 2013). The CWMS is a non-statutory framework document that also recommended the establishment of zone committees – one of which is Selwyn-Waihora. Each zone committee has its own tailored objectives that are required to align with the CWMS and which are intended to form the basis of zone committee chapters of the now operative Land and Water Regional Plan. The Environment Canterbury (Temporary Commissioners and Improved Water Management) Act 2010 requires the implementation of the CWMS. One of the purposes of the Act is “to address issues regarding the efficient, effective, and sustainable management of freshwater in the Canterbury region” (Parliamentary Counsel Office, 2010). Recommendations have been set out in Selwyn Waihora’s Zone Implementation Programme (ZIP) Addendum that the Selywn-Waihora Zone Committee has established. The addendum was created as it needed to add the limit-setting process outcomes to the original ZIP. Although these recommendations have no statutory weighting, they are intended to be translated into one of the sub-regional chapters of the Canterbury Land and Water Regional Plan. This will happen through the standard RMA process which includes notification, submissions, decisions and adoption (Environment Canterbury, 2012g). This Canterbury Land and Water Regional Plan holds statutory force under the RMA which in turn makes the sub-regional objectives enforceable under the RMA. Figure 5 shows where the Canterbury Land and Water Regional Plan sits and how Regional Plans must give effect to National Policy Statements under the RMA framework. The limit setting approach being used for Canterbury has broadly been adopted by central government for further water reform management under its recently proposed reforms to the NPSFM 2011 and its National Objectives Framework (Duncan, 2013b).

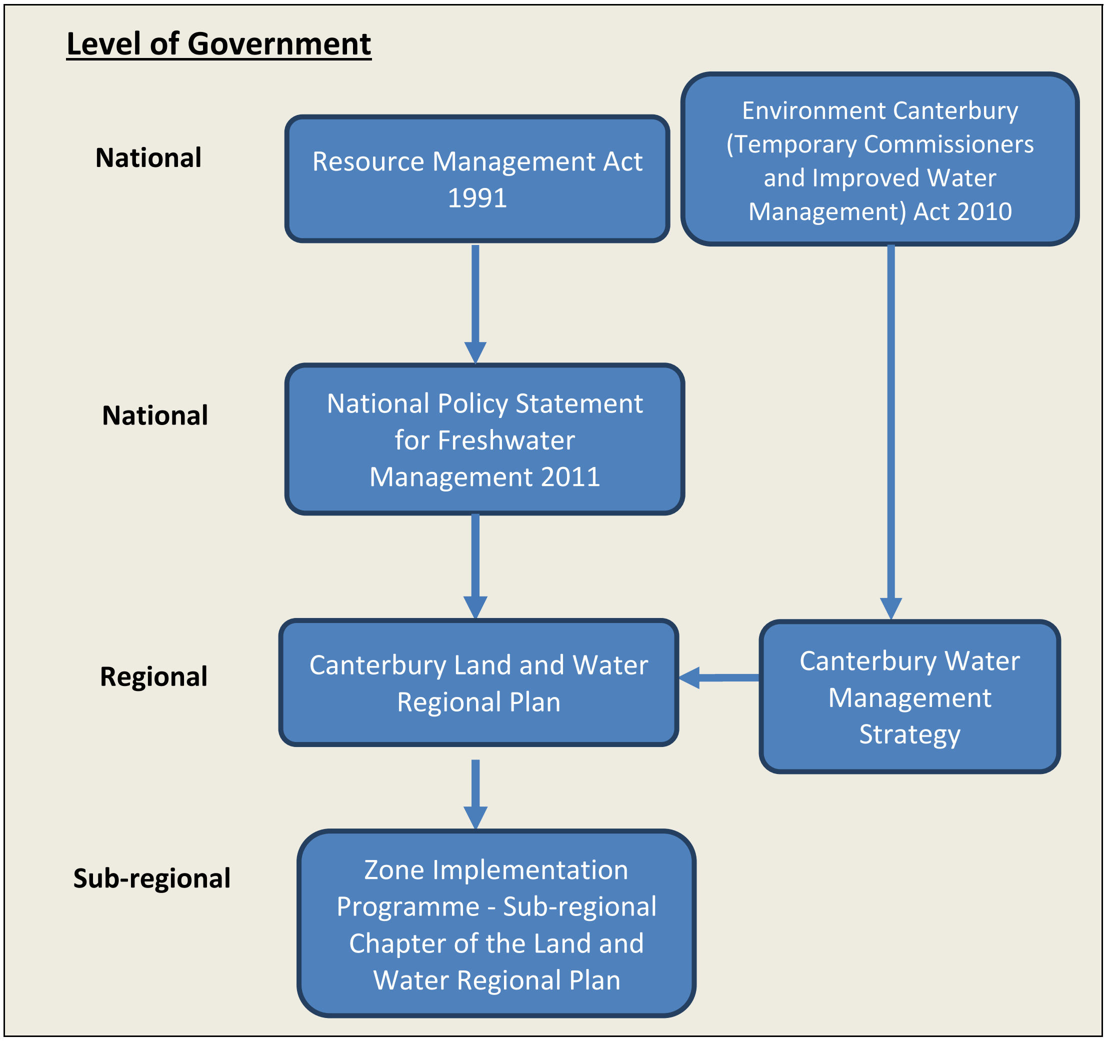

Figure 1 Governance and policy framework for nutrient limit setting for Te Waihora

5.2 Setting of the Nutrient Limits

As stated earlier the limit setting process for the Selwyn Te Waihora catchment was initiated under the Canterbury Water Management Strategy and is to be given regulatory enforcement in the Canterbury Land and Water Regional Plan (Environment Canterbury, 2013b). The recommendations that have been formed appear in the Selwyn-Waihora ZIP Addendum and are driven by the current situation in the catchment. The current situation includes the intensification of land use in the last 20 years, high nitrate concentrations in shallow groundwater and lowland streams, and the accumulation of phosphorus in lake-bed sediments. There is also concern that the lag effect of nutrients in groundwater and legacy phosphorus may cause the health status of Te Waihora to decline further. For the Te Waihora catchment it has been estimated that even if there was no further land use intensification, it could be expected that there will be a 35% increase in the current load of nitrogen entering the lake in the next 10 – 20 years. Therefore, the current water quality levels in Te Waihora and its tributaries are likely to get worse before they get better (Environment Canterbury, 2013b). In addition, the Central Plains Water development has been consented which will lead to further land use intensification in the catchment (Environment Canterbury, 2013b). There are also some key economic and cultural values that underpin the recommendations made in the ZIP Addendum. These include the importance of Te Waihora as a taonga (an object/natural resource highly prized in Maori culture) for Ngai Tahu (Maori tribe of the southern islands of New Zealand), and the importance of agriculture as a significant contributor to local and regional economies (Environment Canterbury, 2013b).

The CWMS proposed ten nutrient management zones (NMZ), which are specified catchment areas relating to a specified node – a point in each region/NMZ where load limits can be set to achieve certain environmental outcomes (Environment Canterbury, 2012a). The Selwyn-Waihora Zone was one of the established nutrient management zones and is the catchment area for the node, Te Waihora. The Selwyn-Waihora Zone Committee was established in 2010 as required under the CWMS (Environment Canterbury, 2011a). Under the CWMS, social, environmental, cultural and economic objectives are to be achieved in parallel. The aspiration for the Te Waihora catchment is "to restore the mauri [the life force that all objects hold] of Te Waihora while maintaining the prosperous land-based economy and thriving communities" (Environment Canterbury, 2013b, p. 5).

The establishment of the Selwyn-Waihora Zone Committee and the production of the ZIP introduced the concept of limit setting for the Te Waihora catchment. From this point the limit-setting for Te Waihora has involved a two-phase process. The first was the non-statutory – the community-led phase - and the second was the statutory RMA phase (Environment Canterbury, 2012g). The first phase, which was the part that focuses on establishing the limits, involved the first six steps as displayed in Figure 6. Step one involved establishing priority outcomes. This was undertaken by the Selwyn-Waihora Zone Committee and Focus Groups. The priority outcomes reflect the values that the community held for the zone. Specifically, the focus groups had to rank the priority outcomes which provided an important indication of the outcomes different groups considered the most important (Environment Canterbury, 2012b). The Focus Groups played an advisory role to the Zone Committee about where to set the limits across the social, cultural, economic and environmental spectrum (R. Duncan, personal communication, January 21, 2014).

Step two (detailed above) involved the establishment of a node, in this case Te Waihora was the established node. Steps three and four involved the development of scenarios based on the priority outcomes. Five scenarios were developed for the Te Waihora case study and these are displayed in Table 1. The third step required establishing limits and involved undertaking an environmental, social, economic and cultural analysis of the different scenarios, utilising a number of models. The models helped to understand the implications of the different scenarios, as well as helping to identify the probable scale of change and impacts. This involved technical work being carried out to inform the Zone Committee and Focus Groups (Environment Canterbury, 2012g). With the use of modelling, and the focus groups own values and backgrounds, the focus groups provided their own evaluations and value judgements (Environment Canterbury, 2012c).

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Step five involved the need for on-farm analysis. This step looked at the likely on-farm costs as a result of the different nutrient limit options (scenarios). This step also involved examining the different mitigation options to understand their cost-effectiveness and impact on on-farm viability. The sixth step involved the discussion and decision making process. Step six involved establishing the catchment nutrient load limits and was based on steps four and five, the environmental, economic, social and cultural analysis, and the on-farm analysis. The Zone Committee asked for the Focus Group's input, and the discussion and decision making process undertaken by the Zone Committee and focus groups aided the Zone Committee to make a number of recommendations on limits and mechanisms to Environment Canterbury. Decisions were then made on the recommendations from the zone committee by the co-governance board which includes Environment Canterbury along with the Te Waihora Management Board and Te Runanga o Ngai Tahu (Environment Canterbury, 2011c). The seventh step shown on Figure 6 is the statutory RMA phase and involved translating the freshwater objectives into load limits, and is described in greater detail in the following paragraphs (Environment Canterbury, 2012g).

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Figure 7 outlines two steps in this process that are not specifically detailed in the process shown in Figure 6 which are important for this research as they highlight the role modelling had to play as well as how the nutrient limit loads are to be implemented at the farm-scale. Environmental modelling has been a key tool in the process to establish catchment load limits for the Te Waihora catchment. Figure 7 is NIWA's (National Institute of Water and Atmospheric Research) science policy model of limit setting (Norton & Kelly, 2010). Box 1 and 2 (from the left) represent the level of protection sought by the Zone Committee and Focus Groups. The chosen scenario from box 2 is transformed into a periphyton cover percentage (chlorophyll *a* biomass) with the use of ecosystem modelling (Duncan, 2013a; Norton & Kelly, 2010). This figure is then translated into nutrient concentrations (as shown in box 3). Box 4 represents the nutrient load limit for the catchment that is calculated using the nutrient concentrations. Box 5 demonstrates the final step which involves the catchment nutrient load limit being translated down to the farm scale. In Canterbury this is being achieved via nutrient discharge allowances (Duncan, 2013a; Environment Canterbury, 2012h). This final step is key as the allocation of nutrient discharge allowances is the means of implementation of the nutrient limits. The nutrient discharge allowances represent each farm's allowable nutrient contribution to the total catchment nutrient load limit, and is measured in kg/ha/yr (Environment Canterbury, 2012f).

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Fig 7 also illustrates the links between the objectives, limits and the method for implementation (Ministry for the Environment, 2011). The first box (from the left) demonstrates the objectives that are sought by the focus groups and zone committee, while the second and third boxes show these objectives translated into numeric objectives with the use of models. The fourth box defines the limit which is established as a result of these objectives, and the final box outlines the method of implementation (NDA) which is derived from the catchment load limit. The arrows on Figure 7 illustrate that each box is both achieved by the information provided in the box/stage before it, whilst it also influences the box/stage before it.

As previously mentioned, the total nutrient load limits (for diffuse pollution) that have been set for the Te Waihora catchment, are to be distributed amongst all landowners. The seven steps established for the implementation of the catchment load limit for the Selwyn/Waihora watershed are outlined in Table 2 below. Steps three and four outline the limit stages. These steps state that a 850 tonne N allowance for community irrigation schemes such as CPW, and a 520 tonne N allowance for activities beyond the Central Plains Water Scheme and N load limit of 15 kg/N/ha are a result of the overall catchment load limit which has been set at 4800 t/N/year (Environment Canterbury, n.d.c). Step One refers to Good Management Practice, which involves mechanisms that result in decreased nutrient discharges. Land users are expected to operate at or above GMP by 2017, and then to advance this GMP to better and then advanced management practices (Environment Canterbury, 2013b).

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The setting of phosphorus limits has not yet occurred for the Te Waihora catchment. A target for phosphorus concentration within the Lake has been established and included in the proposed Selwyn Waihora chapter of the Land and Water Regional Plan (Notified February 2014). Although no numeric catchment load limit has been established to meet this target, a suite of farm, catchment and lake interventions have been included in the solutions package in order to manage phosphorus (M. Robson, personal communication, February 26, 2014). The main methods for reducing phosphorus and nitrogen differ. For phosphorus the key method will be riparian management, fertiliser/soil management, and lake interventions to address the legacy phosphorus from historical land use. The main tools for nitrogen however, are the nitrogen discharge allocations to land parcels or the use of GMPs. The collection of animal effluent will also be a key method to reducing nitrogen loads (Environment Canterbury, 2013b).

5.3 Numeric Limits Set

As mentioned previously, the recommendations that have been developed appear in the Selwyn-Waihora ZIP Addendum. These recommendations include the catchment nitrogen load limit recommended for the Te Waihora catchment. These recommendations appear in the notified LWRP.

The proposed Solution Package for the catchment nitrogen load has been set at 5,000 t/year. This figure includes both non-point sources (agricultural component) and point sources. Non-point sources account for 4800 t/year and point sources account for 200 t/yr as shown in Table 3. Table 3 also shows the 2011 agricultural contribution of nitrogen which is estimated to be 3200 t/year, although this figure is estimated to be 4100 t/year if lag effects are included (Environment Canterbury, 2013b).

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The water quality target that has been set for the health of Te Waihora is an annual average TLI of 6.5 in the centre of the lake, and a TLI of 6.0 nearer to the lake margins. To reach this target the proposed Solution Package of 5000 tN/yr (point-source discharge inclusive), plus lake interventions and a 50% decrease in the phosphorus catchment load would all need to be achieved (Environment Canterbury, 2013b).

5.4 Power to Regulate

Under the NPSFM, enforceable limits must be set by all regional councils for the purpose of water quality (Ministry for the Environment, n.d.). Regulations are instigated at the national level but the establishment, implementation and enforcement of the limits occurs at the regional level. Additionally, these enforceable limits are required to be both set and implemented.

In general terms, when the limits take effect under the LWRP and an existing land user is leaching more than the Good Management Practice (GMP) loss rates and NDAs, then the land user will have to apply for a resource consent (Environment Canterbury, 2013b). This indicates the regulatory enforcement that is in place for non-point source discharges. Audited Farm Environment Plans will also be a requirement of all properties which exceed 20 ha and for properties which exceed 10 ha if the land use is classified as intensive. These plans will have to include (where relevant) management objectives for nutrient management, irrigation management, soils management, wetlands, riparian and biodiversity management, collected animal effluent management, and cultural health management. These plans have the aim of helping land users to carry out GMP, then progress this to better, and then advanced, management practice (Environment Canterbury, 2013b). The focus of regulation on NDAs for Te Waihora indicates the focus of regulation is being conducted at the farm scale.

The nutrient load limit which has been set for Te Waihora accounts for both point source and non-point source discharges. The load limit for non-point source pollution is calculated by the amount after point-source loads have been accounted for. This means that although point-source discharges are accounted for, there is less of a focus on the limiting of point-source discharges for the nutrient load limits. Point source discharges are currently managed under the RMA with the use of resource consents.

5.5 The Knowledge of Limits

The setting of nutrient limits for the Te Waihora catchment has involved the extensive use of models as described in Figure 7. These models have been utilised both for the establishment of the load limit, and are also required for on-farm use to measure nutrient outputs in audited farm management plans. The establishment of the catchment nutrient limit has involved the use of a model termed CLUES (Catchment Land Use for Environmental Sustainability). This model works by calculating the nutrient load of a waterbody through predictions of land use within the catchment (Lilburne et al., 2011). A model termed Overseer is to be used for the enforcement of nutrient limits via Nutrient Discharge Allowances (NDAs) for Te Waihora. Overseer is a computer model that was initially developed for farmers to assess on-farm nutrient use and movements for the purpose of improving production and reducing environmental impacts (The Foundation for Arable Research, 2013).

The use of Overseer as a regulatory tool has been contentious, with some critical flaws of the Overseer model having been identified. The Overseer model presents a simplified model which is said to be consistent with policy requirements for water quality management. However, for arable crop farming these simplifications may mean Overseer is as yet incapable of modelling the impacts of crop management interventions which occur on a range of time scales (The Foundation for Arable Research, 2013). As a model, Overseer does not have the ability to provide direct measurements of nutrient losses from every property. Rather, the model is based on long term averages of predictive leaching. However, it has been noted the impracticality and high costs that are associated with direct measurements of nutrient losses, with 60 individual samplers calculated to be approximately $50,000 per year (2007 figures) (Environment Canterbury, 2012h). The inaccuracy level of Overseer nutrient loss predictions is plus or minus 30 percent (Duncan, 2013b).

The Overseer model has been continuously upgraded since it was first introduced in 1998. The latest version is version 6 which was introduced in 2012 (Duncan, 2013b). The continuous upgrade of Overseer versions is representative of the move to constantly improve the science supporting the model. Although this would appear desirable, the upgraded versions are resulting in significantly different leaching outputs, with outputs changing drastically for the latest Overseer version. For example leaching outputs between version 5 and version 6 have shown increases by up to 60% (Duncan, 2013b).

Concern has been expressed that the underlying assumptions and operational aspects of the Overseer model are currently not made highly transparent to its users (The Foundation for Arable Research, 2013). From a review conducted of Overseer documents it was difficult to obtain assumptions and operational aspects of Overseer. Although many of the assumptions of the model are disclosed, they are scattered across a raft of documents, with no one document stating all of the assumptions. As well as not being presented clearly, the implications of the assumptions were not explained. The users of Overseer include nutrient management advisors and regulatory authorities, plus the understanding of the model by farmers can be regarded as important. Providing training to all of these groups would ensure that there is a common understanding of the correct application of the model (The Foundation for Arable Research, 2013). Despite its limitations, Overseer is currently regarded as the best and most cost-effective method for estimating nutrient losses (The Foundation for Arable Research, 2013). The data inputs into the Overseer model have been validated with average rainfall and average nitrogen leaching rates from a range of trials (The Foundation for Arable Research, 2013).

Although limits are required to be set for all waterbodies under the NPSFM, the limits do not appear to be set with any regard given to bottom line water quality levels. The CWMS was established with the environment as a first order priority, however, the limit setting process for Te Waihora has shown significant consideration given to the value judgements of Focus Groups within the catchment. The NPSFM Implementation Guide when referring to limits confirms this when it states 'a limit is not just the maximum resource use a waterbody can withstand; rather it is the maximum resource use to achieve the identified objective for that waterbody' (Ministry for the Environment, 2011, p. 15). Therefore, where there is more of an economic focus there is likely to be more agriculture, thus higher nutrient losses, and as a consequence less ecological protection (Duncan, 2013a).

5.6 Scale of Collaboration

Under the CWMS, social, environmental, cultural and economic objectives are all to be taken into account. These values are established through engagement with the community and iwi (Maori community or people) in regard to how they value their freshwater bodies, with this requirement specified in the NPSFM Implementation Guide, as well as forming part of the purpose of the RMA (Ministry for the Environment, 2011). Under the Environment Canterbury (Temporary Commissioners and Improved Water Management) Act 2010, the CWMS is also required to undertake a collaborative approach to limit setting.

The limit-setting process for the Te Waihora catchment has directly involved approximately 90 people (Environment Canterbury, 2012d). Environment Canterbury has the overall statutory responsibility for the limit setting, with responsibility for setting both the catchment nutrient load limits and ensuring that the limits are met (Environment Canterbury, 2012h). However, two key community groups, the Selwyn-Waihora Zone Committee and community focus groups were also involved in the process (Robson et al., 2012). The Selwyn-Waihora Zone Committee is a joint committee consisting of members from Selwyn District Council, Christchurch City Council, Environment Canterbury, one member appointed from each Runanga, and between four and six community representatives. The key functions of the Zone Committee, as outlined in the Selwyn-Waihora ZIP, are to: develop solutions in the Selwyn-Waihora zone, facilitate community involvement, keep relevant councils/committees informed, and work with neighbouring Zone Committees and the Regional Council. The Regional Committee also works alongside the Selwyn-Waihora Zone Committee. The Regional Committee's focus is on infrastructure related to managing large scale storage/transfer of water across the Canterbury Plains (Environment Canterbury,2011c).

The stakeholder Focus Groups also had a relatively significant role in the limit-setting process. These groups consisted of four to eight people from a wide range of interests, with 13 focus groups in total as shown in Table 4. The main role of these groups was to assess the acceptability (or not) of the various scenarios, based on information provided to them from a range of models, as well as the use of their own value judgements. Through this method the Focus Groups provided advice to the Zone Committee on the questions that the Zone Committee wanted answered (R. Duncan, personal communication, February 18, 2014). It is stated that that the people in the focus groups drew "on their experiences, values, background and vision for the future" (Environment Canterbury, 2012d, p.

1). The stakeholder groups would, along with a facilitator, assess the acceptability of each of the scenario impacts. This communication between the Focus Groups is undertaken through structured discussions via a deliberation process. According to AgResearch (a Crown Research Institute)– the facilitators of the deliberation process – limit setting involved collective learning with dialogue and learning between stakeholders to view their perspectives, competing outcomes and trade-offs that were required to achieve a balance of competing outcomes (Robson et al., 2012). Communication between the Focus Groups and scientists was also evident as the members of the Focus Groups had the opportunity before meetings to ask questions of the scientists, and at times the Canterbury Regional Council staff, of the limits and any associated issues (R. Duncan, personal communication, February 18, 2014).

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Although there was a deliberation process which utilised learning with dialogue and learning between stakeholders, many of the end-decisions of focus groups were recognised through the use of sticky dots. For example when judging whether the outcomes in the ZIP were being met to an acceptable level, each Focus Group was required to place a red, blue or green sticker next to each outcomes (the coloured dots representing the acceptability; green = acceptable, red = unacceptable, blue = don't have enough information). Reasons for the decisions were also required next to each sticky dot (refer to Appendix A for an example of the sticky dot process) (Environment Canterbury, n.d.).

Although the Focus Groups did have an input through informing the recommendations made by the Zone Committee, it was ultimately the Zone Committee who provided the recommendations to Environment Canterbury's Commissioners and decided where the line had to be drawn across the sustainability objectives (Environment Canterbury, 2012f).

5.7 Summary

The limit setting for Te Waihora indicates that regulation is occurring from the central government level for the development of limits but implementation of these limits is occurring at the regional government level. The primary focus of regulation is at the farm level with the use of nutrient discharge allowances. These NDAs are developed through the use of predictive modelling which is used extensively for limit setting in Te Waihora. The combination of the predictive modelling along with extensive input from the catchment Focus Groups has helped to establish the numeric limits. The following chapter provides the characteristics of limit setting for Chesapeake Bay based on the same categories, with a comparison of these two case studies provided in the cross-case analysis following that.

6. Limit Setting for Chesapeake Bay

This chapter focuses on limit setting in Chesapeake Bay with specific examples from the state of Delaware. The governance for the Chesapeake Bay limit-setting is outlined as well as an overview of the process of setting the TMDL (Total Maximum Daily Load), the numeric limits which have been set, the power to regulate diffuse pollution, the knowledge of limits, and the scale of collaboration.

6.1 Governance

Initiatives aiming to reduce pollutants from agriculture and other sources within Chesapeake Bay have existed since the beginning of the 1960's. Despite these initiatives, Chesapeake Bay is being exposed to increased pollution pressures and sources that these initiatives have failed to reduce (Sims & Volk, 2013).

In the United States, the Clean Water Act 1972 (CWA) is the overarching legislation specific to water quality and the discharge of pollutants to waterways. This Act was previously known as the Federal Water Pollution Control Act, however it was amended in 1972 to become the Clean Water Act. Amongst other modifications, the amended Act recognised the importance of addressing the issues associated with non-point source pollution (US Environmental Protection Agency, n.d.f).

This Act has the overall goal that all water in the US will be both fishable and swimmable. One of the requirements, under Section 303(d) of the Act is that jurisdictions must every two years develop a list of waterways that are classified as 'impaired' by pollutants and which do not meet water quality standards. For every waterway that is classified as being 'impaired' a Total Maximum Daily Load (TMDL) must be developed (US Environmental Protection Agency, 2010). For the first 20 years since its implementation, Section 303(d) was mostly ignored by the US Environmental Protection Agency (USEPA) and US states. However, in the mid-1990s TMDLs gained increased recognition as it became apparent that non-point source discharges were having significant impacts on the water quality of thousands of water bodies. It was realised that surface water quality was still significantly impaired even with point source controls in place (Mandelker, 1989). The influence of a number of court cases initiated by environmental groups also led to the requirement for further compliance with section 303(d) (Hoornbeek et al., 2013).

The majority of Chesapeake Bay and its tidal waters have been classified as impaired, and since the year 2000 plans have been underway for the establishment of a TMDL. Finally on December 29, 2010, a TMDL was established for Chesapeake Bay by the US EPA. The TMDL resolved commitments such as a number of consent decrees, Memorandums of Understanding, and the Chesapeake Bay

Foundation settlement agreement of 2010. Also, on May 12, 2009, the Executive Order 13508 was issued by US President Barack Obama. This Order directed the Federal Government to lead a new effort to restore and protect Chesapeake Bay and its catchment. To meet this Executive Order the Chesapeake Bay TMDL was developed as a keystone commitment in the strategy formed by 11 federal agencies (US Environmental Protection Agency, 2010).

As Chesapeake Bay spans seven states, the setting of the overall TMDL occurs at the USEPA level with some input from states. Specifically at the state level, the TMDL is allocated accordingly between states where limits are allocated within each state with the use of a Watershed Implementation Plan (WIP). The policy framework structure is shown in Figure 8, with the corresponding level of government for each stage shown alongside.

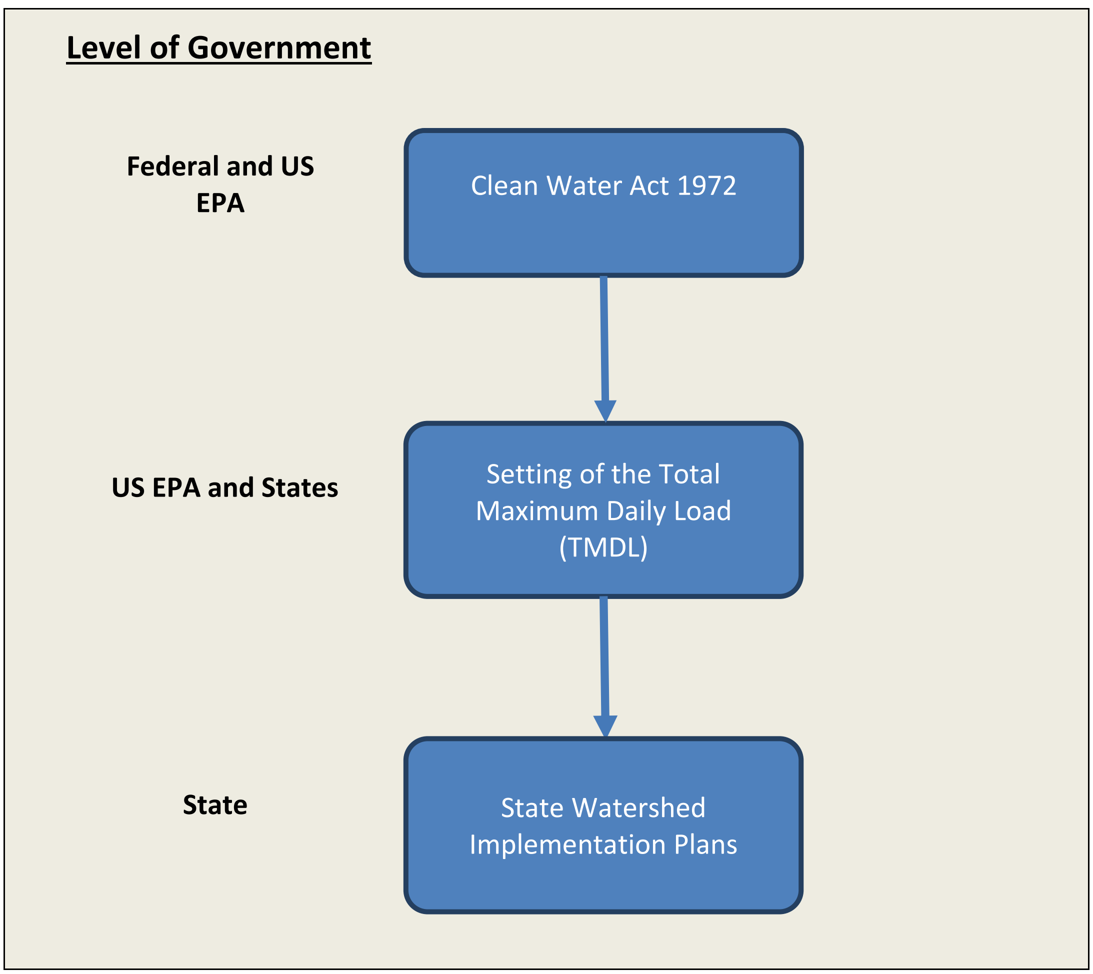

Figure 2 **The governance and policy framework in the United States for setting TMDLs with the corresponding level of government shown**

6.2 Setting of the Total Maximum Daily Loads

The establishment of a Total Maximum Daily Load (TMDL) for Chesapeake Bay was initiated by a number of factors. The Clean Water Act 1972 requires that waterways classified as impaired must have a TMDL developed. The Executive Order issued by US President Obama also required the restoration and protection of Chesapeake Bay and its catchment (US Environmental Protection Agency, 2010).

Total Maximum Daily Loads (TMDLs) are effectively a pollution budget (Copeland, 2012) which have the purpose of estimating the quantity of pollution that a water body can receive while still complying with the water quality standards that have been set for that area (Hoornbeek et al., 2013). Thus limits are set on the total quantity of nutrients that can enter a specified waterbody. The Chesapeake Bay TMDL was officially established in 2010 by the USEPA in a bid to restore the Bay after previous attempts had failed to make sufficient progress. Although the TMDL is usually referred to as being a single allocation in Chesapeake Bay, it is actually made up of 92 smaller TMDLs, representing the different tidal segments of Chesapeake Bay (US Environmental Protection Agency, 2010).

The first step for the setting of the Chesapeake Bay TMDL involved the EPA and seven jurisdiction partners defining an overall TMDL allocation and dividing this up between jurisdictions and major river basins. Deriving this allocation involved a significant amount of monitoring data, scientific modelling, peer-reviewed science and interaction with the jurisdiction partners. The development of the TMDL allocations in the Chesapeake Bay catchment involved the use of what is known as the Phase 5.3 Watershed Model (also known as the Bay Watershed Model) and the Chesapeake Bay Water Quality and Sediment Transport Model. These models were used to estimate the assimilative capacity (loading capacity) of Chesapeake Bay according to a set of water quality standards (US Environmental Protection Agency, n.d.g). Modelling was also used to estimate the pollutant loading that was present from all pollutant sources in the Chesapeake Bay catchment. With the estimation of the pollutant load in the catchment, an analysis was carried out to determine what reductions were required to reach the assimilative capacity (US Environmental Protection Agency, n.d.g).

The second step involved the development of a Phase I Watershed Implementation Plan (WIP). WIPs are one of the key components of the Chesapeake Bay TMDL and are required from all jurisdictions. They have a strong emphasis on the use of current and future Best Management Practices (BMPs) to achieve the TMDL targets (Sims & Volk, 2013). BMPs play a key role for the restoration of the Bay and include practices such as tree planting and land retirement. Once the total allocations of nitrogen and phosphorus have been established for the whole catchment and divided accordingly between each state, it is the WIPs that identify how each state will achieve the nutrient allocation targets (US Environmental Protection Agency, n.d.b). The WIPs subdivide the target loads to set limits between the different pollutant source sectors (Delaware's Chesapeake Interagency Workgroup, 2010). This provides states with discretion as to where to rest liability for pollution. For example states may choose to rest the liability on urban pollution sources even if agriculture is the main source.

Specifically the WIPs detail the exact reductions and control measures that will be required to achieve reductions from point source and non-point source pollution (Copeland, 2012). The Phase I WIPs (which were developed in December 2010) detail how each jurisdiction will achieve the target nutrient limits set for them. As part of this the jurisdictions create sub-allocations between different users of point source and non-point source sectors. This has been undertaken with the use of Chesapeake Bay Programs' Scenario Builder and the Phase 5.3 Watershed model. To set the sub-allocations that have been established, each jurisdiction produced a range of implementation strategies. The sub-allocations and implementation strategies formed the WIPs, which resulted in a completed TMDL. These WIPs were however, first subject to checks from the EPA to ensure jurisdiction and river-basin allocations were being met (US Environmental Protection Agency, 2010).

Phase II WIPs were also required and have now been reviewed by the EPA. These WIPs describe how the jurisdictions will work with particular localities over five years to reduce impairment levels. Phase III WIPs are required from all jurisdictions by 2017, and are to detail any changes that are required to meet the 2025 goal (refer to Table 5). The WIPs are particularly beneficial as they can be customised towards each individual state (Copeland, 2012). The use of the short-term 2-year milestones is important to inform both the government and public of the progress that is occurring with the clean-up plans (Copeland, 2012).

As a part of the multi-part accountability framework established by the USEPA, each jurisdiction is also required to set 2-Year Milestone goals that outline the paths that will be taken toward achieving 60% and 100% implementation rates by 2017 and 2025, respectively (as shown in Table 5) (Sims & Volk, 2013). The jurisdictions are also required to evaluate their progress with the use of annual model simulations which include the most up-to-date data regarding BMP implementation progress, and contingency plans must also be created in case the original plan is not successful. If the jurisdictions do not follow through with the strategies they establish, then the USEPA will enforce consequences upon the jurisdictions (Sims & Volk, 2013). The USEPA has also stated it would ensure enhanced oversight of jurisdiction activities if the jurisdictions do not follow through with the strategies (Sims & Volk, 2013)

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6.3 Numeric Limits Set

The TMDL for Chesapeake Bay sets a limit of 185.9 million pounds (equivalent to approximately 84,000 tonnes) of nitrogen per year with this pollution limit having been further divided by jurisdiction and major river basin creating 92 smaller TMDLs. The TMDL for phosphorus for the Chesapeake Bay catchment has been set at 12.5 million pounds (5,700 tonnes) per year (US Environmental Protection Agency, n.d.-d). These figures stated mean that (using 2009 as a baseline) there is a required 20% reduction in N and 24% reduction in P within the catchment area to achieve the TMDL and hence protect and restore Chesapeake Bay.

The TMDL approach includes the addition of point source discharges, non-point source discharges, and a margin of safety as shown in the below calculation (US Environmental Protection Agency, 2010):

$$TMDL = \sum WLA + \sum LA + MOS$$

Where WLA is the total of waste load allocations (point sources), LA is the total of load allocations (non-point source), and MOS is the margin of safety – this is adding an amount or discharge.

The margin of safety is a required component of the TMDL calculation as stated under section 303(d) of the CWA. This section states that the purpose of the margin of safety is to take into account "any lack of knowledge concerning the relationship between effluent limitations and water quality" (US Environmental Protection Agency, n.d.c).

The load allocation and waste load allocations include both existing and expected future discharges of non-point source pollution. The load allocation also accounts for natural background sources, although these are usually distinguished from non-point sources (US Environmental Protection Agency, n.d.e). The nutrient limit load which has been allocated to Delaware is shown in Table 6. This table also shows the estimated nutrient load limits for the 2017 and 2025 targets.

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6.4 Power to Regulate Diffuse Pollution

At a Federal level the requirement for states to set a TMDL is mandatory for any impaired water body according to section 303(d) of the Clean Water Act (US Environmental Protection Agency, 2010). However, at the Federal level there is no requirement for states to actually implement the TMDL (Copeland, 2012).

A significant difference arises surrounding the regulatory enforcement of point source and non-point source discharges. Point source discharges are implemented through regulatory requirements at a Federal level via the traditional system of the National Pollutant Discharge Elimination System (NPDES) permits (Hoornbeek et al., 2013). Non-point source discharges however, are not regulated at a Federal level. Federal regulatory measures could be introduced if states fail to meet the required targets with the USEPA stating it would ensure enhanced oversight of jurisdiction activities (Sims & Volk, 2013).

Although there are no Federal regulations on non-point source discharges, some states do have regulatory measures in place for non-point source discharges (Hoornbeek et al., 2013). As the Chesapeake Bay catchment spans seven states there are varying policies at state level in the catchment. Just two of the states have regulations surrounding manure application and the use of agricultural chemical fertilizers. West Virginia is an example of a state in Chesapeake Bay that has no regulatory requirements for non-point source pollution (Hoornbeek et al., 2013). Delaware however, has regulatory measures in place for fertiliser use and manure management – identified as two of the main nutrient pollutant sources (Perez, Cox & Cook, 2009). Delaware also has the Delaware Nutrient Management Law (which has existed for some years before the introduction of the Chesapeake Bay

TMDL). This law requires land owners with more than eight animal units or who apply nutrients to more than 10 acres of land to use a Nutrient Management Plan (Perez, Cox & Cook, 2009).

Concentrated Animal Feed Operations (CAFOs) where animals are confined for 45 days or more within a 12 month period, are treated as a point source pollution. They are therefore also regulated by the NPDES permit system under the CWA. Therefore states have been requested by the USEPA to issue permits to CAFOs and produce policies that are either consistent with or more rigorous than the Federal protocols (Sims & Volk, 2013). Poultry is an example of a CAFO and 80% of poultry animals are either permitted or are about to be permitted. This figure is significant compared to other livestock animals such as dairy, beef and swine, for which approximately only 35% are permitted under clean water permits (Perez, Cox & Cook, 2009).

Where no regulatory requirements are in place for non-point source discharges at the state level, voluntary Best Management Practices (BMPs) tend to be the primary implementation tool (Hoornbeek et al., 2013). The strategies that are being used by the states differ according to the major agricultural operations that exist in the region. In the case of Delaware, where significant poultry production is present, the strategies have an emphasis on poultry litter storage structures, composting and relocation strategies (Sims & Volk, 2013). Practices such as the development of buffer strips and wetlands, which consequently involve cropland loss have been found to be unpopular, particularly due to the recent increase in commodity prices (Sims & Volk, 2013).

The use of incentive programs is a key characteristic of the Chesapeake Bay TMDL, particularly where there is a lack of regulatory measures in place. Under the US Farm Bill the implementation of conservation measures by agricultural operators is supported with cost share funds from the USDA Natural Resources Conservation Service and the Farm Service Agency (Sims & Volk, 2013). The monetary incentives come from both Federal and state level, as state funding alone would not be sufficient to achieve the required results (Sims & Volk, 2013). "Certainty" programs are another incentive idea which is beginning to emerge in the Chesapeake Bay catchment. Such programs provide agricultural operators (who enroll into the program) to gain immunity from further environmental regulations for a certain time period. However, these programs do not provide immunity from Federal regulations such as the rules surrounding CAFOs. To enrol in such a program (which helps farmers to know they are operating in a known regulatory environment and decreases financial risk) farmers have to meet a minimum level of conservation through methods such as installing a BMP or a new nutrient management technique (Sims & Volk, 2013). The use of voluntary programs, particularly monetary incentive programs come at a great cost. Between 1987 and 2011 the USEPA have provided more than (US) $3 billion to address non-point source pollution problems across the United States (Hornbeek et al., 2013).

6.5 Knowledge of Limits

The two main models used to estimate the nutrient limit loads for Chesapeake Bay were the Phase 5.3 Watershed Model and the Chesapeake Bay Water Quality and Sediment Transport Model. The Phase 5.3 Watershed Model is based on the Hydrological Simulation Program – Fortran (HSPF) which uses a range of data to simulate the processes that occur in a watershed. This model is usually calibrated with decades of water quality and other data. As well as being used for the all-encompassing Chesapeake Bay TMDL, the Phase 5.3 model is also being used by the Chesapeake Bay watershed states and local governments. All documentation, calibration data, the Model Operations Manual, model scenario output and more can be accessed in the public domain via web servers as it is an open source (Shenk & Linker, 2013). This would suggest that the model has been used in a very transparent manner. Monitoring data was collected over a number of decades from hundreds of stations to deliver direct measures of the water quality in Chesapeake Bay. Of these stations, 162 were monitored consistently throughout this period. The methodologies behind all sampling methods have been precisely detailed and are available for the public to view (US Environmental Protection Agency, 2010). The USEPA has stated that this significant monitoring data and calibration associated with the models helped to 'minimize the uncertainty of the suite of Bay models' (US Environmental Protection Agency, 2010, ch. 5, p.1).

A number of other models were used to provide the inputs for the two main models described above. These models, along with other data were used as inputs for the Scenario Builder. Scenario Builder is effectively a large spreadsheet that provides all of the relevant data in one place which is then required for the Bay Watershed model. As well as providing all of the relevant input data, the Scenario Builder document also provides any assumptions and transformations of the raw data and details of exactly how the data is used in the watershed model (J. Volk, personal communication, December 3, 2013). A key part of the TMDL has involved defining nutrient quantities of land use decisions such as BMPs. It is the use of Scenario Builder that has allowed such practices to be quantified (Chesapeake Bay Foundation, 2013b). With the use of these models, the nutrient loads that have been set for Chesapeake Bay had the aim to protect the living resources of the Bay and to meet water quality standards across a variety of water quality parameters (US Environmental Protection Agency, 2010).

A review was conducted by the author with regard to the transparency of the models and data for the Chesapeake Bay TMDL, with a significant amount of information found that provided detailed information as to the uncertainties and limitations of any calculations. In addition to documents such as Scenario Builder, states such as Delaware have included an entire section outlining the specific issues and concerns with the modelling that has been used in the Delaware WIP. These issues and concerns are outlined for each section of the nutrient loads including agriculture and stormwater (Delaware's Chesapeake Interagency Workgroup, 2010). When increased information is available the Chesapeake Bay Program has agreed to continuously upgrade the TMDL models with this new data through a review process (Sims & Volk, 2013).

6.6 Scale of Collaboration

The establishment of the TMDL allocation for the entire Chesapeake Bay catchment was carried out by the USEPA with some input from representatives of each of the seven states. However, the allocation of the TMDL within each state provided much more control to the individual state.

Public participation was included with a formal public review of the draft TMDL. This process involved more than 14,000 comments from the public (US Environmental Protection Agency, 2010). These were gathered over a period of 45 days in which 18 public meetings were held within the Chesapeake Bay catchment, as well as a number of smaller stakeholder focused meetings (Sims & Volk, 2013). Stakeholder groups involved in these meetings included local governments, environmental groups, agricultural groups, homebuilder and developer associations, and wastewater industry representatives. In terms of the outcomes of the public comments, it is stated that final allocations of the TMDL for each state were 'supplemented by public comments' (US Environmental Protection Agency, 2010). This public participation was undertaken near the final stages of the TMDL development. To increase interaction with the public, websites were set up providing information on the TMDL and WIPs. Webinars were also held to educate the partner organisations and stakeholders (Sims & Volk, 2013). The inclusion of public involvement in the development of TMDLs is a requirement under the Clean Water Act, however, the extent of public involvement within each state has tended to vary (US Environmental Protection Agency, n.d.g).

The formation of the WIPs within each state offered stakeholder and public input at a second stage. In Delaware an Interagency Workgroup was established to play a role in the Delaware Phase I WIP. This Workgroup consisted of a number of representatives from each division of the Delaware Department of Natural Resources and Environmental Control, as well as representatives from:

- Department of Agriculture
- Department of Transportation
- Office of State Planning Coordination
- County Conservation Districts
- Other relevant stakeholders

Subcommittees were formed within the Workgroup for each source sector, including agriculture, stormwater, and wastewater. These subcommittees had a number of roles including recommending and reviewing the sub-allocation methodologies to the different pollutant sources. A number of the subcommittees also invited other stakeholders to participate during the development of the Phase I WIP. Following the submission of the draft Phase I WIP, the Interagency Workgroup members travelled throughout Delaware to meet with town and stakeholder groups and give presentations on the draft plan. At the end of meetings, stakeholders had the chance to answer questions, and were also given the chance to submit questions within a certain time frame after the presentations (Delaware's Chesapeake Interagency Workgroup, 2010).

6.7 Summary

The setting of a TMDL for the impaired waterbody of Chesapeake Bay is mandatory under the CWA. The setting of the limits is largely carried out at a Federal government level with a significant emphasis on the use of predictive modelling to derive limits. Approaches for implementing the limits and managing diffuse pollution are largely taken out at the state level using a range of voluntary and regulatory approaches used by states for implementation. The following chapter provides a cross-case analysis of limit setting for Te Waihora and Chesapeake Bay.

7. Cross-case Analysis

This chapter provides a comparison between the two case studies of Te Waihora and Chesapeake Bay. The similarities and differences between the two cases are provided based on the aspects that were focused on for each case study. A summary table of the key differences between the two case studies is provided at the end of this chapter.

7.1 Governance

Prior to the actual setting of the nutrient load limits, there is alignment between the governance of limit setting for the two case studies. At a national/Federal level both case study locations have overarching legislation for limit setting. For Te Waihora this is the Resource Management Act and for Chesapeake Bay it is the Clean Water Act. Under the RMA a tool termed a National Policy Statement has been utilised for New Zealand/Te Waihora limit setting (National Policy Statement for Freshwater Management). Rather than a separate tool requiring limit setting, the CWA has a section (section 303(d)) that can require a TMDL to be set. Te Waihora has an added component in terms of governance with the CWMS also requiring limit setting at a regional level within Canterbury.

At a state/regional level there is also alignment in the governance/policy process of limit setting. Te Waihora has the Zone Implementation Programme (Addendum) outlining the catchment load limits and methods for achieving this limit. This ZIP will have legal effect under the sub-regional chapter of the Canterbury Land and Water Regional Plan. Each state in the Chesapeake Bay catchment has a Watershed Implementation Plan specific to the state which allows the state to allocate limits to specific pollution sources and provide the methods for achieving the set limit. This shows that both case studies are comparable in that at a higher level of governance there is directive to set limits which is left up to the regional or state government. Although alignment is evident at both a national/federal level and state/regional level, Te Waihora appears to have a greater focus at the regional level whilst Chesapeake Bay is at the federal level.

7.2 Power to Regulate Diffuse Pollution

At a national/federal level both the NPSFM and CWA require the setting of nutrient limits. However, the NPSFM requires the setting of *enforceable* limits, whereas the CWA requires the setting of limits, but not *enforceable* limits. Additionally, the NPSFM requires nutrient limits to be established for *all* freshwater bodies in New Zealand (New Zealand Government, 2011). Therefore limit setting was required in the Te Waihora catchment regardless of whether the lake was polluted or not. For Chesapeake Bay the CWA only requires TMDLs to be established if a water body is classed as being 'impaired' by nutrients (i.e. it fails to reach certain water quality standards) which Chesapeake was (US Environmental Protection Agency, 2010).

Another key feature of the regulation of limit setting at the federal level in the United States is the lack of ability to require the implementation of TMDLs. Although TMDLs are required to be set for impaired waterways, the CWA does not actually have any regulatory functions to require the implementation of TMDLs (Copeland, 2012). However, in the case of the TMDL for Chesapeake Bay a stringent accountability framework has been set. The accountability framework includes the WIPs and two-year milestones which are required to ensure limits are met. If limits are not implemented and met there is the potential for federal regulations to be employed for diffuse pollution. This differs from Te Waihora where the NPSFM requires both the setting and implementation of nutrient load limits.

The regulatory enforcement of non-point source discharges differs significantly between the two case studies. For Te Waihora, catchment nutrient loads are calculated for the entire catchment and then divided into a nutrient discharge allowance at the farm scale. The regulatory enforcement of limits for Te Waihora is therefore focused at the farm scale. The NDAs have statutory enforcement by land use rules under the Canterbury Land and Water Regional Plan. If land users exceed the nutrient discharge allowance they have to apply for a resource consent. For Chesapeake Bay there are no federal regulatory requirements for the enforcement of non-point source discharge limits. This means that a voluntary approach is often used instead of a mandatory approach. However, this is not the case for the entire Chesapeake Bay catchment as it spans seven states with each state having varying regulations around non-point source pollution. For example Delaware has regulatory measures in place for fertiliser use and manure management, and also has in place the Delaware Nutrient Management Law.

When states have used voluntary measures for the implementation of nutrient load limits, incentive programs are used alongside these voluntary measures, often providing monetary incentives. The use of certainty programs is also increasing, where land users are provided immunity from future regulations so long as they meet a minimum level of conservation.

7.3 The Knowledge of Limits

The limit setting for both case studies has involved extensive use of predictive modelling. Te Waihora has focused on a series of models including the CLUES model for calculation of catchment load limits, and Overseer for the enforcement of limits at a farm scale. Chesapeake Bay has relied predominantly on the use of the Phase 5.3 Watershed Model and the Chesapeake Bay Water Quality and Sediment Transport Model. The Phase 5.3 Watershed Model for Chesapeake Bay used calibrated data with decades of water quality and other data to improve the credibility of the model data outputs.

In terms of the models used, the evaluation of both case studies shows that the uncertainties of both models have been identified. However, the overview of information to locate data input, uncertainties and assumptions of the two case studies showed that differences exist. Obtaining the limitations and assumptions of the models used for limit setting in Te Waihora was difficult. Although the limitations and assumptions could be found, they were scattered throughout a raft of documents rather than in one accessible location. For Chesapeake Bay, any model inputs, limitations and assumptions were comparatively easy to access. All documentation and calibration data was made accessible to the public. The use of the Scenario Builder document also provided input data for the models within one document.

In terms of the basis of limits, it appears that limits have been set on different values. For Te Waihora, the limits were strongly influenced by values across a wide spectrum (environmental, economic, social and cultural) with the extent of these depending on the values that stakeholders of the catchment held. There did not appear to be any bottom-line water quality values that limits were set on. The limits for Chesapeake Bay were set largely by the USEPA scientists with the use of modelling and monitoring data. The intention of the water quality standards for Chesapeake Bay is to improve the health of the Bay and the surrounding waters, through meeting water quality standards across a broad spectrum of indices. This indicates a relatively strong reliance on scientific and environmental values for limit setting in Chesapeake Bay.

Another difference identified for the knowledge of limits, is the inclusion of a Margin of Safety for the Chesapeake Bay numeric limit. Te Waihora did not include an equivalent to this Margin of Safety.

Both case studies have referred to the continuous updating of the models when new research is derived. For Chesapeake Bay it is mentioned that this will be undertaken when this research is developed. The Overseer model for Te Waihora has already been updated numerous times since it was established in 1998, with leaching outputs showing up to a 60 per cent increase between version 5 and version 6 of Overseer.

7.4 Scale of Collaboration

Chapters' Four and Five show that both limit setting regimes have adopted collaborative approaches at different stages and to different extents. The limit-setting process for Te Waihora appears to have utilised a collaborative process with the wide range of focus groups coming together to share and express their values surrounding the scenarios they were presented with. The Focus Groups also had the opportunity for discussions with scientists regarding the limit setting and any issues of concern.

A collaborative approach is a requirement under the CWMS with up to 90 people involved in the limit setting process for Te Waihora. The use of the sticky dot method for decision making was a characteristic of the limit setting approach for Te Waihora.

The involvement of the community and stakeholders in the original setting of the catchment-wide TMDL for Chesapeake Bay was included at a later stage than it was for Te Waihora. Public participation was incorporated during the *review* of the draft TMDL. The public were given a comment period, which in the New Zealand/Te Waihora case study was given during the RMA phase for inclusion of limits into the regional plan. The use of public meetings and focused stakeholder meetings were incorporated as part of the limit setting approach for Chesapeake Bay.

7.5 Summary

Table 7 provides a summary of the characteristics identified in this chapter for limit setting in Te Waihora and Chesapeake Bay.

Table 1 Summary of characteristics for limit setting in Te Waihora and Chesapeake Bay

Te Waihora	Chesapeake Bay
Policy/Governance Framework: • RMA • NPSFM and CWMS • ZIPs and LWRP	Policy/Governance Framework: • CWA • TMDL • WIPs
Power to Regulate Diffuse Pollution: • NPSFM requires enforceable limit setting for all water bodies • Regulatory enforcement of point source and non-point source discharges via land use rules	Power to Regulate Diffuse Pollution: • CWA requires limit setting for impaired waterways • Regulatory enforcement of point source but not point source discharges (or very little) as USEPA does not have jurisdiction
Knowledge of Limits: • Extensive use of modelling • Limits set on Focus Groups values • Difficult to assess the limitations and assumptions of modelling in one document • Updating of Overseer model	Knowledge of Limits: • Extensive use of modelling • Limits set to water quality standards • Limitations and assumptions of modelling accessible in one document, plus the inputs in Scenario Builder • Plans to update modelling • Inclusion of Margin of Safety
Scale of Collaboration: • Focus groups and Zone Committee had major role in setting limits • Focus group meetings, discussion and deliberation, use of sticky dot approach	Scale of Collaboration: • EPA and jurisdiction partners had main role in limit setting • Public/stakeholder involvement once draft completed – “fine tuning” phase

8. Discussion

The cross-case analysis in the previous chapter combined with the theory from the conceptual framework both provide valuable information to answer the question of what challenges these limit setting approaches present for water quality policy implementation.

In terms of implementation, both case studies have similar time frames in place. For Chesapeake Bay the timeline of the TMDL shows that full implementation of pollution control measures will be in place by 2025 (US Environmental Protection Agency, 2010). For Te Waihora most methods are to be in place for near full implementation by 2022.

8.1 Governance

Governance is an important element for limit setting as it determines the overall structure and level of government at which limits are set. Examination of the governance for the two case studies shows a similarity at which level of government limit setting was focused. Both case studies have overarching legislation for limit setting. In New Zealand limit setting is directed from the national level but negotiated at the regional level. For the United States, limits have been directed from the Federal government, and negotiated at both a Federal and state level.

This indicates for both case studies that at a higher level of governance there is directive to set limits which is left up to the regional or state government. However, for Te Waihora, the governance framework for limit setting tends to give more discretion to the local level of government than is the case for Chesapeake Bay. In terms of implementation this difference may be quite significant. As the limits in Chesapeake Bay were set predominantly by the USEPA, implementation can be hindered given the lack of legitimacy of the science that limits were derived from (Cash et al., 2006). When decisions are made at the national/Federal government level there tends to be higher levels of reluctance towards the uptake of these decisions. This top down approach is not generally appreciated at a local level.

The implementation of nutrient limits in Te Waihora focuses at the regional government level which is likely to improve the legitimacy of the process and thus improve the success of implementation.

It must be noted however, there is a difference in the size of the catchment area between the two case studies. Establishing limits at the local level is much more straightforward for Te Waihora as the catchment only spans one regional authority. For Chesapeake Bay, however, the extensive size of the catchment means that the catchment is spread across seven states/jurisdictions. Thus a higher level of governance is necessary to set limits to encompass the significant number of jurisdictions within the catchment.

8.2 Power to Regulate Diffuse Pollution

The cross-case analysis highlighted a number of differences regarding the power to regulate diffuse pollution for the two case studies. Voluntary (carrot) and regulatory (stick) approaches are two of the main tools available to governments to influence stakeholder behaviour. Both case studies have identified an increased shift from voluntary to regulatory approaches in order to control diffuse pollution.

For Te Waihora, national legislation requires the setting of *enforceable* limits for diffuse pollution. National legislation for Chesapeake Bay also requires the setting of limits, although does not require the setting of *enforceable* limits. This difference has led to one of the most significant variances between the two case studies which is the regulation of non-point source pollution. For Te Waihora there is to be regulation of both non-point source and point source pollution, while Chesapeake Bay is only regulating point source pollution and does not have strict controls over non-point source pollution. The difference in the regulatory approach between the two case studies represents the classic case of the 'carrot' versus 'stick' approach.

The strict regulatory approach that is to be in place for Te Waihora represents the use of the 'stick' approach. The regulatory focus on NDAs at the farm scale presents both benefits and challenges for implementation. A defined NDA for each farm provides a specific value for nutrient outputs allowed, which provides a clear focus/goal for land users when implementation is required. However, the 'stick' approach may result in reduced cooperation and resentment between polluters and authorities (Alberini & Segerson, 2002). Assigning maximum discharges of diffuse pollution to land users, as is done for point source discharges, will not prove to be as straightforward. Land users may resent regulation of maximum discharges if they are aware of the complex characteristics, including uncertainties, of diffuse pollution. There may be issues surrounding the credibility of the process as the setting of a NDA may be imposed with a relatively high level of uncertainty. Ensuring compliance with the NDAs may prove difficult and is likely to involve a significant volume of resources.

Although there has been a shift from a voluntary to mandatory approach for Chesapeake Bay in terms of the requirement to set limits, the limit setting process for diffuse pollution focuses on both voluntary and regulatory approaches. This patchwork of both federal and state regulatory and voluntary measures highlights the holes present in the regulatory framework. In terms of implementation, a voluntary approach provides both benefits and challenges. Without regulatory enforcement and the lack of resentment that may be associated with this, a voluntary approach has the ability to minimise implementation lags due to improved cooperation between polluters and authorities. However, in contrast, the lack of regulatory measures for Chesapeake Bay does raise concern that nutrient limits may not be adhered to if polluters are not forced to provide environmental protection beyond what they deem sufficient (Alberini & Segerson, 2002). The implementation of limits in Chesapeake Bay through a voluntary approach may also prove to be difficult, due to the characteristics of diffuse pollution. Diffuse pollution can often seem to be invisible to land users as the impacts occur "off-site" or "off-farm" (Blackstock et al., 2010, p. 5632). Therefore land users are likely to reject ownership of the pollution. In this case without the use of a mandatory approach, a voluntary approach may find it difficult to change the behaviour of land users. Additionally, when farmers are not required to implement nutrient management plans they are often less likely to. This is due to a number of reasons including: hesitancy to accept links between agricultural activities and poor water quality, disagreement over the method to setting yield goals, and limited acceptance of crop and soil nutrient science (Perez, 2011).

The variation in levels of regulation between the Chesapeake Bay states has the potential to create obstacles for the successful implementation of the limits. The seven jurisdictions that are found within the Chesapeake Bay catchment are separated by political boundaries as opposed to water catchment boundaries. There are difficulties with the management of natural resources which cross jurisdictional boundaries (Burkhart, Jacobson & Finley, 2012). The implementation of methods and approaches within the State WIPs may face constraints particularly for those land users/owners near the boundaries of a state. This is because there may be regulatory measures in place for one state, but next door the use of voluntary measures may be the predominant implementation method. The differences in implementation methods, even though both land users are within the same water catchment, could lead to issues surrounding the legitimacy of the implementation methods of the limits. Enforcing regulatory measures under the CWA for diffuse pollution may be one of the only methods to create consistency across multiple states within one water catchment. This approach has been supported by a number of groups stating that only when such an approach is in place would any significant positive influence be noticed (Perez, Cox & Cook, 2009).

The use of incentive programs in Chesapeake Bay emphasises the use of the carrot approach. As a number of the non-point source conservation practices are voluntary in nature, funding provides an incentive for land owners to undertake such practices to reduce nutrient discharge (Sims & Volk, 2013). As voluntary approaches may provide a lack of take up for implementation in Chesapeake Bay, the use of incentive programs such as financial incentives from the Farm Services Agency has been identified by Lubell (2004) as improving the success of voluntary approaches. Lubell (2004) has also identified incentive programs as being an important motivation tool for voluntary approaches.

The use of financial incentives that have been used for Chesapeake Bay is particularly important for the agriculture sector. Agriculture is the largest contributor of nutrients to Chesapeake Bay, and "economic viability is a central concern of the agricultural community" (Lubell, 2004, p. 344). Therefore the use of financial incentives is likely to improve uptake by farmers in the Chesapeake Bay catchment. As identified in previous chapters, 'certainty' programs are another incentive program that are being utilised for Chesapeake Bay. The threat of regulation that these certainty programs employ, is likely to incentivise farmers and other land users to increase current conservation levels. These programs are likely to improve the success of implementation where voluntary approaches have been utilised.

Although such incentive programs have the potential to increase the success of implementation of limits, they they do have drawbacks. Incentive programs (particularly financial incentive programs) are very costly. Although the United States may have funding for such programs, New Zealand does not appear to have the funds for such costly programs. TMDLs throughout the United States have required significant amounts of funding, with the USEPA already having spent $1 billion on the TMDL program in the US over 15 years from the start of the 21st century (Hoornbeek et al., 2008). With such high costs it is questionable how long the United States can continue to support such programs. These costs could thus threaten to undermine the complete and successful implementation of such incentive programs.

The cross-case analysis chapter highlighted another difference between the two case studies in terms of the power to regulate diffuse pollution. This is because for Te Waihora limits are required to be set *and* implemented, whereas limits are only required to be set for Chesapeake Bay with no requirements for implementation. The absence of the requirement for TMDLs to be implemented in Chesapeake Bay is due to the lack of federal requirements under the CWA. With no federal enforcement in place, there may be little urgency for states to implement the nutrient limits. For the Chesapeake Bay TMDL this risk of a lack of take up is reduced with the use of the Accountability Framework. However, other TMDLs throughout the United States may not have such methods in place, leading to the possibility of failed implementation.

A distinct difference for the requirement of nutrient limits to be set at the national/federal level is present for the two case studies. Limit setting for New Zealand is based a preventive approach, whilst for the United States more of a reactive approach has been taken. Both approaches provide benefits and consequences for implementation of nutrient limits. The preventive approach that has been taken in New Zealand under the NPSFM which involves the setting of limits for all waterbodies regardless of their water quality levels. The use of a preventive approach in environmental management has increased significantly since the 1970's, and the New Zealand nutrient limit setting reflects this (Wynne, 1992). From an environmental perspective, a preventive approach is seen as desirable as it aims to prevent the negative impacts from environmental degradation (in the case of Te Waihora the water body was already polluted before limit setting was introduced). In the United States a reactive approach has been adopted which only requires TMDLs to be set for impaired waterways. This reactive approach means that waterways will already be experiencing degradation, and implementation clean-up costs are likely to be higher than if a preventive approach had been used.

However, a preventive approach may not be as seamless and effective as it first appears. A preventive approach is usually more likely to rely on predictions about unknowable futures through predictive modelling than a reactive approach is. In respect of setting nutrient limits it may be increasingly difficult to distinguish where limits should be set to prevent water degradation. This is because there is a heavy reliance on anticipatory knowledge and a focus on upstream processes to determine the level of technological investment and restriction levels that are required (Wynne, 1992). This preventive approach may open up questions regarding the credibility and legitimacy of limits and the science that sits behind them, thus creating difficulties for implementation.

8.3 The Knowledge of Limits

Previous chapters have highlighted that limit setting for both case studies has involved the use of a string of predictive models. This predictive modelling has been one of the main means of determining nutrient limits and is a useful tool for providing valuable predictions. Two primary downfalls that have been identified with the use of models are uncertainty and a lack of transparency. Uncertainty is almost unavoidable as data will often never reflect the true complexity of systems in the natural environment (Heathwaite, 2003). The simplification of the Overseer model particularly for arable cropping is an example of uncertainties associated with models. A lack of transparency however, is a factor which can be avoided, but is at the discretion of those who have created the model. Snelder et al. (2013) has stated that creating a transparent process when setting limits means that the limits are likely to be more readily accepted by stakeholders when they are implemented. Therefore although the models used for setting limits in both Chesapeake Bay and Te Waihora are embed with uncertainties they are likely to be more readily accepted if these uncertainties are communicated to those who the limits will affect.

The cross-case analysis has identified that limit setting in Chesapeake Bay has been undertaken in a more transparent process than it has been for Te Waihora. Chesapeake Bay has placed a heavy focus on “unveiling the black box” (J. Volk, personal communication, December 3, 2013). As uncertainty is unavoidable when models are used, to increase the credibility and saliency for implementation it is important that the uncertainty is recognised, acknowledged and disclosed to the community and stakeholders (Robson et al., 2012). Improving the credibility of the science to stakeholders of the nutrient limits is a key step for implementation as it can otherwise be difficult to "gain consensus and change behaviour" when the outputs from modelling are highly disputed (Hendry & Reeves, 2012). The increased transparency for Chesapeake Bay is likely to result in stakeholders viewing the process as a more credible and salient one than is the case for Te Waihora. Therefore this level of transparency could lead to the more successful implementation of limits for Chesapeake Bay than for Te Waihora (in respect of the transparency of models). To improve implementation for Te Waihora, enhancing the transparency of the Overseer model will be paramount. This could be undertaken with stakeholder inclusion incorporated into the development of the model.

The cross-case analysis indicates that both case studies have undertaken or plan to undertake continuous upgrades of the predictive models that have been used. For Chesapeake Bay these upgrades have not yet occurred, but will do when more up-to-date research is available. The Overseer model for Te Waihora has already undergone numerous upgrades since it was first established. The continual upgrade of the models indicates the use of an adaptive management approach. The upgrade of models makes sense as the complexity and level of input information is constantly increasing with new discoveries in science and increasing monitoring results. The upgrading of the models reflects the statement made by the Ministry for the Environment (2011) that limit setting is not a static process and requires constant fine-tuning. An adaptive management approach is useful, particularly for limit setting where there is a great deal of uncertainty present (Stankey, Clark, & Bormann, 2005). Although this approach cannot eliminate uncertainty, it does allow for continual increasing accuracy of the results. However, an adaptive management approach may create difficulties for implementation. As was noted for the Overseer model, an upgrade from version 5 to version 6 resulted in a significant predicted nutrient output increase. If the Overseer model is constantly upgraded, the level of predicted nutrient outputs may constantly change. This is likely to pose serious issues for implementation, with stakeholders sensing no credibility and saliency in the models used for the limit setting process. Additionally, it would be difficult for stakeholders who have limits imposed on them to change in response to the science, particularly when business models require a high degree of certainty.

For Te Waihora, the limits have been strongly influenced by values across a wide spectrum (environmental, economic, social and cultural) with the extent of these depending on the values that stakeholders of the catchment held. There did not appear to be any bottom-line water quality values that limits were set to. The limits for Chesapeake Bay were set largely by the USEPA scientists with the use of modelling and monitoring data. The intention of the water quality standards for Chesapeake Bay is to improve the health of the Bay and the surrounding waters, through meeting water quality standards across a broad spectrum of indices. This indicates a relatively strong reliance on scientific and environmental values.

The New Zealand Government has however, very recently introduced proposed amendments to the NPSFM 2011. It is stated by the Ministry for the Environment that the current issues 'may result in decisions that provide insufficient protection for environmental or cultural values, or unnecessarily constrain economic growth and development' (Ministry for the Environment, 2013). One of the proposed amendments involves the establishment of a National Objectives Framework. Included in this is a choice of national values for regional councils to apply to freshwater bodies, as well as two compulsory national values – 'ecosystem health' and 'human health for secondary contact'. Water quality attributes including nitrogen and phosphorus are to be managed for each of these values. Each attribute will be scaled from A – D, with D representing the 'national bottom line' (Anderson Lloyd Lawyers, 2013). This means that numeric bottom lines will be set for ecosystem health and human health. This would align more so with the Chesapeake limit setting, which relies on setting targets to achieve sufficient water quality levels.

The implementation of nutrient limits faces a raft of other challenges, one of which is the lengthy period of time it can take for diffuse-sourced nutrients to reach surface water. This lag time can mean that the delay in time for nutrients to enter waterways from existing land uses will likely result in minimal positive water quality changes in the short term. There is potential that water quality levels could even decline before they improve. Te Waihora is affected by 'legacy' phosphorus as well as lag effects from nitrogen. For the Te Waihora catchment it has been estimated that even if there was no further land use intensification, it could be expected that there will be a 35% increase in the current load of nitrogen entering the lake in the next 10 – 20 years (Environment Canterbury, 2013b).

The Delmarva Peninsula in the Chesapeake Bay catchment has been found to be an area of slow moving ground water resulting in the slow movement of nutrients. In this area analysis of U.S. Geological Survey data has shown that it takes approximately 20 to 40 years for the groundwater (and hence nitrogen) to flow through the peninsula's porous aquifers into the rivers and streams. This slow flow and hence lag effect of the nutrients means that it may take longer than first thought for water quality improvements to take effect in Chesapeake Bay (US Geological Survey, 2013).

Lag times have the potential to create serious issues for the implementation of nutrient limits. Although initial implementation may not be hindered by lag effects, it is likely to cause difficulties for on-going implementation. This is because stakeholders may have adopted the appropriate practices and reduced nutrient discharges, yet be disheartened by the disconnect between action on land and nutrient concentrations in water. This is problematic as society "usually desires a relatively quick return on investments" (Sandford & Pope, 2013, p. 13330). Stakeholders are likely to question the credibility of nutrient limit policies and thus there will be reduced stakeholder buy in. For this reason, it is important that authorities communicate the impacts of lag effects to stakeholders.

8.4 Scale of Collaboration

The Cross-Case Analysis has shown that there have been different levels of collaboration at various stages throughout the limit setting process for Te Waihora and Chesapeake Bay. However, overall the limit setting processes have indicated increased collaboration in Te Waihora compared to Chesapeake Bay. The level of collaboration during the limit setting process is likely to result in different levels of success for the implementation of the limits as discussed below.

The level of collaboration undertaken in the limit setting process for Chesapeake Bay reflects more of a traditional top down approach to the management of water quality. The setting of limits for Chesapeake Bay as a whole were predominantly undertaken by the USEPA with some input from jurisdiction representatives. This indicates that decisions on where to draw the lines for limits were primarily left to government agencies and scientists and hence the use of a technocratic approach. The use of the technocratic approach in Chesapeake Bay, whereby decisions are primarily made by technical experts, may engender some credibility for implementation of the limits. This is on the basis that members of the public may often believe that scientists and technical experts have the most up-to-date knowledge in the relevant field to make informed decisions.

However, a technocratic approach often means that stakeholder involvement is given a minimal role (Sabatier et al., 2005). This was evident in Chesapeake Bay where public participation was only included in the review of the draft TMDL. Although public and stakeholder meetings were included, these were mostly held after much of the modelling had been undertaken. Thus the role of the public and stakeholders in the limit setting process for Chesapeake Bay was minimal and was left to the 'fine-tuning' phase. Although stakeholders and public could provide some 'tweaking' of the limits, there was little opportunity for original thinking (J. Volk, personal communication, December 3, 2013). This minimal level of collaboration which generally only occurred during the final stages, constrained the input of stakeholders and the public. Additionally, it is much more difficult for the public/stakeholders to provide a significant contribution regarding the nutrient load limits when they are not included in the early stages of decision making. These issues are likely to impact on the credibility and legitimacy of the limits and have implications for on-the-ground implementation. There is likely to be hesitancy towards the adoption of the limits as stakeholders may have questions over the limits due to the lack of public input. Stakeholders may also hold doubts over the lack of transparency and thus potentially affecting the credibility of the limit setting process. Additionally, without stakeholder involvement at early stages there is reduced incentive to implement the limits.

The limit setting process for Chesapeake Bay indicated an increased level of collaboration during the later stages of the process. In terms of implementation the inclusion of stakeholder input is important as it is often these stakeholders that consume or utilise the natural resources – such as farmers. Focused stakeholder meetings were held as part of limit setting for individual states. This is important as it is stakeholders (such as farmers) that make the resource decisions which cause the environmental issues (Lubell, 2004). Therefore on-the-ground implementation is likely to be more successful if stakeholders have contributed their ideas and have resolved any disputes before implementation of the nutrient limits.

The level of collaboration for limit setting in Te Waihora was relatively high. Focus Groups provided a significant input and influenced the direction of limit setting from the early stages. This level of collaboration for Te Waihora illustrates the shift over the past 20 – 30 years whereby collaboration has increased as the approach to water quality management by individual, single-functional governmental agencies has received substantial criticism (Sabatier et al., 2005). This is partly due to the lack of local knowledge that governmental agencies may provide (Sabatier et al., 2005). This collaborative approach for Te Waihora is likely to improve credibility and legitimacy of limits leading to increased success of implementation. This is because a collaborative approach is said to improve understanding and trust among stakeholders and often means the process will have the support or at least acquiescence of stakeholders. A collaborative approach is also beneficial as it allows local knowledge to be included. Decisions that are made by government experts who are often not from can have little understanding of local context and issues. This local knowledge for Te Waihora is likely to improve the saliency of the process and therefore will be beneficial for implementation.

Focus Groups had a significant involvement from an early stage and had large discretion over choosing the limits based on their values. Significant discussion and deliberation occurred at the Focus Group meetings, however, many of the end decisions required from the Focus Groups were limited in scope. This is because the Focus Groups often had to provide their decisions according to the sticky dot process. Original thinking was limited by this process, as the Focus Groups had to categorise their decisions into one of only three different outcomes (representative of the three coloured sticky dots). This may have provided frustrations to stakeholders as some of the decisions were already prescribed. Hence, notwithstanding the extent of collaboration, scenarios and issues were pre-determined and aims of limit setting were established by the CWMS targets. Creating a collaborative process is not only important for the public to voice their opinions and concerns, but ultimately it will often lead to greater support of stakeholders meaning that implementation will be less challenging (Sabatier et al., 2005).

9. Conclusion

In a number of dimensions the Te Waihora and Chesapeake Bay limit setting approaches display similar features; however, from this comparative case study research it is evident that there are a range of differences. Both case studies display a similar governance structure with the national/Federal government directing the setting of limits, and the limit setting negotiated at the regional/state government. However, for the Te Waihora case study, the CWMS (along with the NPSFM) was driving the limit setting. There is greater power to regulate diffuse pollution for Te Waihora, with the focus of enforceable nutrient discharge allowances at the farm scale. For Chesapeake Bay a patchwork regulatory framework exists, with differing regulatory and voluntary approaches across the seven jurisdictions. The analysis of the knowledge of limits indicates that limit setting for both case studies relied heavily on predictive modelling. For Te Waihora, nutrient limits were based largely on Focus Groups values. For Chesapeake Bay, limits appeared to be set more so to water quality standards. In terms of the transparency of limits, Chesapeake Bay had a strong focus on "unveiling the black box", whilst uncovering the limitations and assumptions for modelling in Te Waihora proved to be more challenging. The continuous updating of the models for both case studies represented the use of an adaptive management approach. Although this helps to reduce uncertainties, it can create difficulties with changing nutrient discharge values. The setting of the limits indicated collaboration was present for both approaches though at varying stages and to different extents. As discussed, each of these characteristics has provided a challenge or has aided limit setting implementation, particularly in regard to the credibility, legitimacy and saliency of the approaches.

This research has only touched on a very small number of characteristics for nutrient limit setting. There are many factors beyond those focused on within this research which will also have significant impacts in terms of the implementation of limits. It is therefore important to realise that this research does not provide a complete evaluation of the impacts of limit setting characteristics for implementation.

Whether these two limit setting approaches have the capacity to manage diffuse pollution is questionable. However, this research indicates that there are a number of characteristics which can help to improve the likely success of implementation. Until monitoring results are available it will be difficult to ascertain just how successful these approaches will be. This will be some time away as both limit setting processes are at an early stage and changes in land use management can take a significant time period to be reflected in water quality levels with the associated issues of lag effects. Although the management of diffuse pollution by way of setting limits may appear as an ideal method in theory, this research clearly indicates that the complex nature of diffuse pollution does not make the implementation of nutrient limits so straightforward.

9.1 Further Research

The methodology chapter of this dissertation identified a number of limitations associated with this research, including the focus on only one of the Chesapeake Bay States. Further research could be conducted on the other states present in the Chesapeake Bay catchment to gain more insight into the different policies relating to the TMDL in Chesapeake Bay. An examination of the other states may reveal differing results for the implementation of nutrient limits within Chesapeake Bay and hence produce different comparisons between Te Waihora and Chesapeake Bay.

Further research could also be undertaken once the nutrient limits at both case study locations have been implemented and been in place for a considerable time period. This research would be particularly useful to identify the success of the nutrient limits and to identify what factors may be causing successful implementation and which factors may be hindering the success of nutrient limit implementation.

10. References

Alberini, A., & Segerson, K. (2002). Assessing Voluntary Programs to Improve Environmental Quality *Environmental and Resource Economics, 22*, 157-184.

Anderson Lloyd Lawyers. (2013). *Bottom Lines Recommended for Water Quality*. Retrieved from http://www.andersonlloyd.co.nz/bottom-lines-recommended-for-water-quality/

Baxter, P., & Jax, S. (2008). Qualatative Case Study Methodology: Study Design and Implementation for Novice Researchers. *The Qualatative Report, 13*(4), 544 - 559.

Benham, B., Zeckoski, R., Yagow, G., & Ekka, S. (2006). *TMDL Implementation: Characteristics of successful projects*. VA Tech University.

Blackstock, K. L., Ingram, J., Burton, R., Brown, K. M., & Slee, B. (2010). Understanding and influencing behaviour change by farmers to improve water quality. *Science of the Total Environment*, 5631-5638.

Bodansky, D. (1991). Scientific Uncertainty and the Precautionary Principle. *Environment*, 43-44.

Brown, I. (2010). *Nutrient management and the land use and water quality project*. Retrieved from http://files.ecan.govt.nz/public/selwynzcpres/LU%20%20WQ%20S_W%20Zone%20Committee%2014%20Dec%202010.pdf

Campbell, N., D'Arcy, B., Frost, A., Novotny, V., & Sansom, A. (2004). *Diffuse Pollution: An introduction to the problems and solutions*. London, England: IWA Publishing.

Cassell, C., & Symon, G. (2005). *Essential Guide to Qualatative Methods in Organizational Research*. Gateshead, England: SAGE Publications.

Chesapeake Bay Foundation. (2013a). *Chesapeake Bay News: Chesapeake Bay Foundation report card measures "modest" improvement in Bay health.* Retrieved from http://www.chesapeakebay.net/S=0/blog/post/chesapeake_bay_foundation_report_card_measures_modest_improvement_in_bay_he

Chesapeake Bay Foundation. (2013b). Estimates of County-Level Nitrogen and Phosphorus Data for use in Modeling Pollutant Reduction: Documentation for Scenario Builder Version 2.4.

Chesapeake Bay Foundation. (n.d.). It's more than just "the Bay". Retrieved from http://www.cbf.org/about-the-bay/more-than-just-the-bay

Chesapeake Bay Program. (2012a). Physical Characteristics. Retrieved from http://www.chesapeakebay.net/discover/bayecosystem/physical

Chesapeake Bay Program. (2012b). *The Chesapeake Bay Watershed*. Retrieved from http://www.chesapeakebay.net/discover/baywatershed

Copeland, C. (2012). Clean Water Act and Pollutant Total Maximum Daily Loads (TMDLs): Congressional Research Service.

D'Arcy, B., & Frost, B. (2001). The role of best management practices in alleviating water quality problems associated with diffuse pollution. *Science of the Total Environment, 265*(1-3), 359-367.

Delaware's Chesapeake Interagency Workgroup. (2010). *Delaware's Phase I Watershed Implementation Plan*.

Duncan, R. (2008). Problematic practice in integrated impact assessment: the role of consultants and predictive computer models in burying uncertainty. *Impact Assessment and Project Appraisal, 26*(1), 53-66.

Duncan, R. (2013a). Converting Community Knowledge into catchment Nutrient Limits: A Constructivist Analysis of a New Zealand Collaborative Approach to Water Management. *Nature and Culture, 8*(2), 205-225.

Duncan, R. (2013b). Regulating agricultural land use to manage water quality: the challenges for science and policy in enforcing limits on non-point source pollution in New Zealand. *Land Use Policy Journal, 41,* 378-387.

Environment Canterbury. (2011a, 2011 August 3). *About the Zone Committees*. Retrieved from http://ecan.govt.nz/get-involved/canterburywater/committees/Pages/about-zone-committees.aspx

Environment Canterbury. (2011b). *Canterbury Natural Resources Regional Plan*. Retrieved from http://ecan.govt.nz/publications/Plans/nrrp-chapter-1-operative-110611.pdf.

Environment Canterbury. (2011c). Selwyn Waihora ZIP. Retrieved from http://ecan.govt.nz/publications/General/cw-draft-selwyn-waihora-zip.pdf

Environment Canterbury. (2012a). *An equal-allocation method for allocation of a total nutrient load wihtin a nutrient management zone*. Christchurch, New Zealand: Landcare Reseach.

Environment Canterbury. (2012b). *Focus Group Workshop # 2 Summary: Setting Limits in the Selwyn Te Waihora Catchment*. Retrieved from http://ecan.govt.nz/publications/Plans/selwyntewaihora-focusgroup-210212-workshop2-summary.pdf

Environment Canterbury. (2012c). *Focus Groups*. Retrieved from http://ecan.govt.nz/publications/Plans/selwyntewaihora-focusgroup-210212-focus-groups-julia-crossman.pdf

Environment Canterbury. (2012d). *Information Sheet: Limit setting - an introduction*. Retrieved from http://ecan.govt.nz/publications/Plans/selwyn-te-waihora-focus-group-info-sheet1.pdf

Environment Canterbury. (2012e). *Key Topic Area for discussion: Selwyn Waihora Focus Group Workshop*. from http://ecan.govt.nz/publications/Plans/selwyn-tewaihora-key-topic-areas-discussion-131212.pdf

Environment Canterbury. (2012f). *Newletter on limit setting: Selwyn Waihora Zone update*. Retrieved from http://ecan.govt.nz/publications/Plans/selwyn-waihora-information-sheet-2-000812.pdf

Environment Canterbury. (2012g). *Selwyn Waihora limit setting process: An overview of current status in 2012*. Retrieved from http://ecan.govt.nz/publications/Plans/selwyn-tewaihora-current-state-overview-290312.pdf

Environment Canterbury. (2012h). *The preferred approach for managing the cumulative effects of land use on water quality in the Canterbury region: A working paper*. Retrieved from http://ecan.govt.nz/publications/Reports/luwq-preferred-approach-report-jan2012.pdf.

Environment Canterbury. (2012i). *Proposed Canterbury Land and Water Regional Plan: Section 32 Report*

Environment Canterbury. (2013a). *Canterbury Water Management Strategy Targets: Progress Report June 2013*. Retrieved from http://ecan.govt.nz/publications/Council/cmws-targets-reports-sept.pdf.

Environment Canterbury. (2013b). Selwyn Waihora ZIP Addendum. Retrieved from http://ecan.govt.nz/5CEDB2FF-8CDF-4B5C-AA6F-1C4245809D10/FinalDownload/DownloadId-B31EE3FAA4572EABB1793943F299AD61/5CEDB2FF-8CDF-4B5C-AA6F-1C4245809D10/publications/General/zip-addendum-at-150613-v6.pdf

Environment Canterbury. (n.d.). Te Waihora Sticky Dot Process Example. Retrieved from http://ecan.govt.nz/publications/Plans/selwyn-te-waihora-current-deliberation-results-sub-outcome.pdf

Environment Canterbury (Temporary Commissioners and Improved Water Management) Act 2010 (2010). Retrieved from http://www.legislation.govt.nz/act/public/2010/0012/latest/DLM2850313.html?search=ts_act%40bill%40regulation%40deemedreg_Environment+Canterbury+(Temporary+Commissioners+and+Improved+Water+Management)+Act+2010_resel_25_h&p=1

Environmental Defence Society. (n.d.). Planning Documents: National Policy Statements. Retrieved from http://www.rmaguide.org.nz/rma/plandocs/natpolicystmts.cfm

Freeman, M. (2012). Stormwater Meanderings: Stormwater discharges - integrating technical knowledge with the resource consent process. Retrieved from http://www.freemanenvironmental.co.nz/resources/Stormwatermeanderingsnewsletter10.pdf

Green, M. O. (2013). Catchment sediment load limits to achieve estuary sedimentation targets. *New Zealand Journal of Marine and Freshwater Research, 47*(2), 153-180. doi: 10.1080/00288330.2012.757241

Hamel, J., Dufour, S., & Frotin, D. (1993). *Case Study Methods*. Newbury Park, CA: Sage Publications.

Heathwaite, A. L. (2003). Making process-based knowledge usable at the operational level: a framework for modelling diffuse pollution from agricultural land. *Environmental Modelling and Software, 18*, 753-760.

Hendry, S., & Reeves, A. D. (2012). The regulation of diffuse pollution in the European Union: Science, governance and water resources management. *International Journal of Rural Law and Policy, 0*.

Hoornbeek, J., Hansen, E., Ringquist, E., & Carlson, R. (2013). Implementing Water Pollution Policy in the United States: Total Maximum Daily Loads and Collaborative Watershed Management. *Society & Natural Resources: An International Journal, 26*(4), 420-436. doi: 10.1080/08941920.2012.700761

Hughey, K. F. D., Johnston, K. A., & Lomax, A. J. (2013). *Te Waihora/Lake Ellesmere: State of the Lake 2013*. In Hughey, K. F. D., Johnston, K. A., Lomax, A. J., & Taylor, K. J. W. Christchurch: Waihora Ellesmere Trust.

Hughey, K. F. D., & Taylor, K. J. W. (2009). Te Waihora/Lake Ellesmere: State of the Lake and Future Management (pp. 150). Christchurch: EOS Ecology.

Lilburne, L., Elliott, S., Bidwell, V., Shanker, U., Kelly, D. and Hanson, C. 2011. *Hurunui catchment-scale land use and water quality modelling report*. Prepared for Environment Canterbury.

Lubell, M. (2004). Collaborative Watershed Management: A View from the Grassroots. *The Policies Studies Journal, 32*(3).

Ludwig, D., Hilborn, R., & Walter, C. (1993). Uncertainty, Resource Exploitation, and Conservation: Lessons from History. *Science, 260*.

Mandelker, D. R. (1989). Controlling Nonpoint Source Water Pollution: Can it be done? *Chicgo Kent Law Review, 65*(2).

Map Resources. (n.d.). Poster Size USA Map. Retrieved from http://www.mapresources.com/usa-maps/usa-poster-size-maps/poster-size-usa-digital-vector-raster-terrain-map-usa-xx-302248.html

Margerum, R. D. (2011). *Beyond Consensus: Improving Collaborative Planning and Management*: Massachusetts Institute of Technology.

Maryland State Archives. (n.d.). Retrieved from http://msa.maryland.gov/msa/mdmanual/01glance/html/mdglance.html

Ministry for the Environment. (2011). *National Policy Statement for Freshwater Management 2011: Implementation Guide*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2013). *Freshwater reform 2013 and beyond*. Wellington: Ministry for the Environment.

Ministry for the Environment. (n.d.). Proposed National Policy Statement for Freshwtaer Management: Preamble. Retrieved from http://www.mfe.govt.nz/publications/rma/nps-freshwater-management/nps-freshwater-management.html

Minnesota Pollution Control Agency. (2008). Nutrients: Phosphorus, Nitrogne Sources, Impact on Water Quality - A General Overview. Retrieved from http://www.pca.state.mn.us/index.php/view-document.html?gid=7939

National Institute of Water and Atmospheric Research. (2011). International water pollution conference kicks off in Rotorua.

New Zealand Government. (2011). *National Policy Statement Freshwater Management 2011*. Retrieved from http://www.mfe.govt.nz/publications/rma/nps-freshwater-management-2011/docs/nps-freshwater-mgnt-2011.pdf.

Norton, N., & Kelly, D. (2010). *Current nutrient loads and options for nutrient load limits for a case study catchment: Hurunui catchment*. Christchurch, New Zealand: National Institute of Water & Atmospheric Research Ltd.

Parliamentary Commissioner for the Environment. (2012). Water Quality in New Zealand: Understanding the Science. Retrieved from http://www.pce.parliament.nz/assets/Uploads/PCE-Water-Quality-in-New-Zealand.pdf

Parliamentary Commissioner for the Environment. (2013). *Water quality in New Zealand: Land use and nutrient pollution*. Retrieved from http://www.pce.parliament.nz/assets/Uploads/PCE-Water-quality-land-use-website.pdf.

Perez, M. (2011). Regulating Farmers: Lessons Learned from the Delmarva Peninsula. *Choices, 26*.

Perez, M., Cox, C., Cook, K. (2009). *Facing facts in the Chesapeake Bay - Environmental Working Group*. Retrieved from http://static.ewg.org/reports/2009/FacingFactsInTheChesapeakeBay.pdf

Pidwirny, M. (2006). *Fundamentals of Phsical Geograhy* (2nd ed.).

Robinson, K., & Davies, T. (2013). *Te Waihora/Lake Ellesmere: State of the Lake 2013*. In Hughey, K. F. D., Johnston, K. A., Lomax, A. J., & Taylor, K. J. W. Christchurch: Waihora Ellesmere Trust.

Robson, M., Brown, I., Ford, R., Lilburne, L., Norton, N., & Wedderburn, M. E. (2012). Setting Catchment Water Quality Limits and Implications for Nutrient Management in Canterbury. Retrieved from http://www.massey.ac.nz/~flrc/workshops/12/Manuscripts/Robson_2012.pdf

Ryan, A. P. (1987). The Climate and Weather of Canterbury (Including Aorangi). Wellington, New Zealand: New Zealand Meteorological Service.

Sabatier, P. A., Focht, W., Lubell, M., Trachtenberg, Z., Vedlitz, A., & Matloch, M. (2005). *Swimming Upstream: Collaborative Approaches to Watershed Management* (Vol. Cambridge, MA): Massachusetts Institute of Technology.

Sanford, W. E., & Pope, J. P. (2013). Quantifying Groundwater's Role in Delaying Improvements to Chesapeake Bay Water Quality. *Environmental Science and Technology, 47*, 13330-13338.

Savage, J. A., & Ribaudo, M. O. (2013). Impact of environmental policies on the adoption of manure management practices in the Chesapeake Bay watershed. *Journal of Environmental Management, 129*, 143-148. doi: http://dx.doi.org/10.1016/j.jenvman.2013.06.039

Scientific and Technical Advisory Committee. (2012). Incorporating Lag-Times Into The Chespeake Bay Program: STAC Workshop Report. Edgewater, MD: Chesapeake Bay Program.

Shenk, G. W., & Linker, L. C. (2013). Development and Application of the 2010 Chesapeake Bay Watershed Total Maximum Daily Load Model. *Journal of the American Water Resources Assocition, 49*(5), 1042-1056.

Sims, T. J., & Coale, F. J. (2002). Solutions to Nutrient Management Problems in the Chesapeake Bay Watershed, USA. *Agriculture, hydrology and water quality*.

Sims, T. J., & Volk, J. A. (2013). Nutrient Management Strategiesfor the Chesapeake Bay Watershed, USA: Sustaining Agriculture in the Face of Changes in Science, Policy, and Climate.

Smith, N. (2011). $11.6 million clean up plan for NZ's most polluted lake. Retrieved from http://beehive.govt.nz/release/116-million-clean-plan-nz%E2%80%99s-most-polluted-lake

Snelder, T. H., Rouse, H. L., Franklin, P. A., Booker, D. J., Norton, N., & Diettrich, J. (2013). The role of science in setting water resoure use limits: a case study from New Zealand. *Hydrological Sciences Journal*. doi: 10.1080/02626667.2013.793799

Stankey, G. H., Clark, R. N., & Bormann, B. T. (2005). *Adaptive Management of Natural Resources: Theory, Concepts and Management Institutions*. Portland, OR: Retrieved from http://www.fs.fed.us/pnw/pubs/pnw_gtr654.pdf.

Tellis, W. (1997a). Application of a Case Study Methodlogy. *The Qualatative Report, 3*(3).

Tellis, W. (1997b). Introduction to Case Study. *The Qualatative Report, 3*(2).

Tennoy, A., Kvaerner, J., & Gjerstad, K. I. (2006). Uncertainty in environmental impact assessment predictions: the need for better communication and more transparency. *Impact Assessment and Project Appraisal, 24*(1), 45-56.

The Foundation for Arable Research. (2013). A peer review of Overseer in relation to modelling nutrient flows in arable crops.

US Environmental Protection Agency. (2010). Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment. Retrieved from http://www.epa.gov/3B6DC99D-89D8-4374-BB7E-E9DF3DEEBBAE/FinalDownload/DownloadId-D50A212C4243555C25C81510BDD1BDF4/3B6DC99D-89D8-4374-BB7E-

E9DF3DEEBBAE/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLExecSumSection1through3_final.pdf

US Environmental Protection Agency. (n.d.-a). Bay TMDL - A Commitment to Clean Water. Retrieved from http://www.epa.gov/chesapeakebaytmdl/

US Environmental Protection Agency. (n.d.-b). Chesapeake Bay TMDL: How Does It Work? Ensuring Results. Retrieved from http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/EnsuringResults.html

US Environmental Protection Agency. (n.d.-c, 2012, March 6). Clean Water Act Section 303. Retrieved from http://water.epa.gov/lawsregs/guidance/303.cfm

US Environmental Protection Agency. (n.d.-d). Fact Sheet: Chesapeake Bay Total Maximum Daily Load. Retrieved from http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/BayTMDLFactSheet8_6.pdf

US Environmental Protection Agency. (n.d.-e, 2012, March 6). Glossary. Retrieved from http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/glossary.cfm

US Environmental Protection Agency. (n.d.-f, 2013, April 17). History of the Clean Water Act. Retrieved from http://www2.epa.gov/laws-regulations/history-clean-water-act

US Environmental Protection Agency. (n.d.-g, 2013, September 11). What is a TMDL? Retrieved from http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overviewoftmdl.cfm

US Geological Survey. (2013). New USGS Study on Chesapeake Bay: Groundwater Delaying the Effects of Some Water Quality Actions [Press release]. Retrieved from http://www.usgs.gov/newsroom/article.asp?ID=3723&from=rss_home

von Moltke, K. (1996). *The Precautionary Principle and International Law* (D. Freestone & E. Hey Eds.). Hague, Netherlands: Kluwer Law International.

Waihora Ellesmere Trust. (2014, February 25). *Te Waihora Catchment*. Retrieved from http://www.wet.org.nz/home/attachment/te-waihora-catchment/

Williams, D. (2011, August 26). $12m clean up for NZ's most polluted lake. Retrieved from http://www.stuff.co.nz/environment/5509947/12m-clean-up-for-NZs-most-polluted-lake

Wynne, B. (1992). Uncertainty and environmental learning: Reconceiving science and policy in the preventative paradigm *Global Environmental Change, June*, 111-127.

Yin, R. K. (2009). *Case Study Research: design and methods (4th ed.)*. US: SAGE Publications.

Appendix A

Te Waihora Sticky Dot Process Example

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