An Assessment of Cost Benefit Analysis Approaches to Mangrove Management

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An Assessment of Cost Benefit Analysis Approaches to Mangrove Management

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Executive Summary

Policy regarding effective mangrove management has multiple objectives and an array of permutations and actions to achieve certain objectives. The most suitable response for mangrove management requires consideration of the broader management of the freshwater catchment and harbour/estuary area, within which the mangroves are growing. Land based activities, both historic and current, affect the rates of sedimentation and current distribution of mangroves in the estuaries. The removal of mangroves gives temporary reprieve in areas where they are encroaching or impinging on other activities. In essence, mangrove management can be considered a 'wicked problem', which describes a problem that is difficult to resolve given the complex interdependencies between mangroves and the ecosystem within which they are formed (estuaries and freshwater catchments), and also because there is incomplete knowledge of current and future value sets associated with mangroves in any particular estuary.

Cost benefit consideration is a logical basis for making decisions. Cost benefit analysis is an economic tool that compares the net value of one course of action against another. Cost benefit analysis requires the articulation, measurement and monetisation of the costs and benefits brought about by the change in the course of action. In this report it is applied to the management options for mangroves.

A cost benefit framework is useful for its pluralist approach in identifying the wide range of costs and benefits, and conceptually mapping out the likely effects of a change through scenario building. This would be undertaken on a case-by-case basis at catchment level.

Estimates of costs are readily available from other projects where mangrove removal or riparian management has been instituted. There are however constraints on undertaking a cost benefit analysis, based on the valuation of benefits. The element of uncertainty over current benefits (requiring significant understanding of ecosystem functioning on a catchment level) and future benefits (changing value sets over time) poses a challenge for following the logical methodology prescribed by cost benefit analysis. Cost benefit analysis is firmly grounded in a rational choice paradigm, but policy processes and decision making do not necessarily follow rational processes, as they can be iterative, adaptive and have time-lags inherent. Furthermore a robust rational choice approach may require an inordinate amount of information, which may be costly to gather for the decision taker.

A cost benefit analysis will not augment or facilitate a decision on how best to spend Council money between either mangrove removal or integrated catchment projects. There is no easy 'off the shelf' economic tool to substitute cost-benefit analysis, but a cost effectiveness analysis of mangrove removal and integrated catchment projects is recommended as better deployment of Council resources to answer such a question.

Conventional economic value is based on utility maximisation. However, that may not be the correct goal to pursue. Additional goals could be ecological stability, social equity (both within and across generations, and across species), social acceptance of environmental decisions and efficient allocation of resources.

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1.0 Background

Options for mangrove management are spelt out in a discussion document that was presented to Auckland Council's Environment and Sustainability Forum (ESF) in October 2011. At the meeting it was resolved "that Council staff be requested to undertake an analysis of the costs and benefits of various options for mangrove management, including catchment management, and report back to the Environment and Sustainability Forum". This was in recognition that "long term sustainable management requires integrated management between catchments and the coast, and Council will need to develop and support community partnerships to coordinate both removal, maintenance and restoration projects". Establishing the costs and benefits of options for mangrove management seems a deceptively simple task. However, once it is acknowledged that mangrove management needs to be viewed within the context of broader freshwater catchment and estuarine health, which in turn is affected by land-based activities (current and historical), the complexity of mangrove management compounds. A seemingly simple question over optimal economic strategies for mangrove management (how much to spend on mangroves and what type of projects in which areas?) unmasks some critical issues over contemporary tools for valuation of the natural environment. It forces adressing value sets that may change over time, due to uncertainty – all which affect mangrove values.

Auckland has a significant area of mangrove stands. Estimates obtained from the Ministry for the Environment's land classification database indicate that in the summer of 2001/02 mangroves covered 2641 ha in the Auckland Region (Hauraki Gulf Forum, 2011).[1] There is evidence of the expansion of mangroves, in the Hauraki Gulf harbours, and in the Manukau and Kaipara harbours to the west.

Values assigned to the existence of mangroves range from negative regard when they impinge on recreation (e.g. limiting water access), affect safety (e.g. supporting colonies of birds that compromise air traffic safety) to concern over displacement of ecological systems (e.g. encroachment of sandy beaches and benthic biodiversity by sediments, the habitat for mangroves) to positive regard for the feeding grounds that mangroves provide to species such as the endangered tara-iti/fairy tern, the ecosystem services (e.g. sediment control and harbour health) and environmental services (e.g. flood mitigation, carbon sequestration) that mangroves provide and may provide in the future. The intensity of values are complex on this bi-polar spectrum, and oftentimes competing. They range from individuals and community groups lobbying to secure the rights to mangrove removal in the short term to lobbying for maintaining the longer term functions and services provided by mangroves. There is added uncertainty in the future function of mangroves, or potential ecosystem services provided in the face of expected sea level rise (Horton *et al*., 2008; Hart, 2011).

New regional plan rules regarding disturbance of the foreshore and seabed came into effect in March 2011, allowing for mangrove management in certain areas. These rules are contained in Plan Change 4 Mangrove Management in the Auckland Regional Plan: Coastal (Auckland Regional Council, 2004a). A number of new policies and rules were added to Chapter 16, relating to mangrove management. There is recognition that in some areas careful consideration needs to be given to the effects of undertaking mangrove removal, and that mangrove removal should be avoided where it will threaten the viability or significance of areas identified as having ecological or geological values (Coastal Protection 1 Areas – highest value and most vulnerable areas; and Coast Protection 2 Areas - generally more robust bust still highly valued areas). An example of a vulnerable habitat reliant on mangroves in Auckland (and adjacent Northland sites) is the breeding ground for the critically endangered tara-iti/fairy tern (Brooks, Davis, Baird *et al*., 2011; Miskelly Dowding, Elliott *et al.,* 2008). However, in the areas where the recent expansion of new mangrove stands encroach on other activities and species, mangrove removal may be appropriate. New mangrove stands may adversely affect: the feeding and roosting areas of the numerous wading birds in Auckland's estuaries (such as kuaka/godwit and torea/oystercatcher); drainage systems and public infrastructure; navigation, amenity and recreation uses; heritage, archaeological and ecological sites. The change concerning mangrove management should also be seen in the broader context of the Auckland Plan, which sets

[1] These estimates are based on spectral analysis of satellite images using a minimum mapping unit of 1ha. Studies undertaken by Gao *et al*. (2004) tested the use and accuracy of remote sensing for mangroves in the Waitemata Harbour.

the strategic direction for moving toward integrated management of freshwater, estuarine and coastal systems (see Box 1).

Box 1 Strategic Direction from the Auckland Plan (2012)

Chapter 7 of the **Auckland Plan (2012)** explicitly recognises the integrated and systemic nature of the environment and ecosystems. Chapter 7 has some directives that relate to the freshwater network, coastal receiving environments, levels of degradation and hence aspirations for their restoration:

Directive 7.8

Establish freshwater values and aspirations with communities and make freshwater an identifying feature of Auckland.

Directive 7.10

Manage land to support the values of water bodies by protecting them where they are high and reviving them where they are degraded.

Directive 7.12

Protect coastal areas, particularly those with high values – including special natural character, significant marine habitats and recreational importance – from the impacts of use and development, and enhance degraded areas.

Directive 7.13

Ensure integrated and sustainable management of marine areas through marine spatial planning for the Hauraki Gulf, Kaipara Harbour, Manukau Harbour and west coast.

At the moment, there is no coordinated Council investment plan or budget allocation for the management and monitoring of all catchment projects, including mangroves. Budgetary allocation is made at the Local Board level on a case by case basis, according to community priority. This is akin to the subsidiarity principle, where matters are handled at the lowest or least centralised competent authority.[2] Scaling these projects up to the regional level and assessing overall effects on the Auckland Council area is a crucial question to be addressed. Likely outcomes from planned expenditure on integrated catchment and mangrove management should be assessed. The impact of completing a suite of individual restoration projects will have cumulative effects, that need to be considered together.

In the Local Board Plans 2011, an estimated $22 million has been allocated to a combination of freshwater and coastal restoration projects throughout the Auckland Council area for three years, between 2011 and 2013 (Table 1). Some of this expenditure is for the continuation of legacy projects, while others are for new initiatives. The explicit removal of mangroves is articulated within some of these projects, while other projects have goals of sediment reduction, stream restoration, harbour conservation, biodiversity protection and natural capital maintenance, water quality, improvement to water flows or combinations of these goals, broadly defined as catchment restoration. A significant initiative relates to the establishment of the Manukau Harbour Forum.

[2] Subsidiarity, as an organising principle, suggests that a central authority should perform only those tasks which cannot be undertaken effectively at a more local level.

Table 1. Projected expenditure in the Local Board 2011 Plans.

Local Board	Key project(s) relevant to integrated catchment, freshwater and estuarine restoration, mangrove management	Cost
Franklin	Mangrove and wild oyster removal Water quality improvement projects Manukau Harbour Forum establishment	$235,000 $100,000 $30,000
Papakura	Complement implementation of Pahurehure Inlet Management Plan Continue Programme of mangrove removal around Pahurehure Inlet Water quality monitoring of waterways and Manukau Harbour	$500,000 $600,000 $90,000
Manurewa	Coastline protection, within which mangrove management is identified Mangrove control management plan	$393,000 Advocacy role
Mangere-Otahuhu	Consenting process and removal of mangroves in the two harbours – Manukau and Waitemata (Tamaki Estuary)	$780,000
Otara-Papatoetoe	Otara Lake improvements Joint Tamaki Estuary restoration Joint Manukau Harbour improvement	$6,000,000 $750,000 $750,000
Maungakiekie-Tamaki	Working with the Tamaki Estuary Protection Society Manukau Harbour Forum Community and business education and restoration projects, including planting	$750,000 $100,000 $600,000
Manurewa	Manukau Harbour Forum Coastal preservation (including mangrove removal) Puhinui and Papakura streams clean waterway initiative (restoration including riparian planting)	$393,000 $365,000
Kaipatiki	Inner harbour beach protection and enhancement (stressing balanced mangrove management – not an outright removal of mangroves – and also this figure includes investment in stormwater and wastewater projects)	$1,500,000
Henderson Massey	Ongoing funding of Project Twin Streams network Maintenance Project Twin Stream – streams, tracks, walkways and cycleway	$1,500,000 $1,320,000
Hibiscus Bay	Development and implementation of catchment management plans across the local board area. Continuation of partnership approach to working with community and environment groups	Not scoped or costed as yet. Not scoped or costed as yet.
Puketepapa	Biodiversity management plan for the foreshore and establishment of the Manukau Harbour Forum Ongoing pine tree removal and weed eradication (not mangroves, but harbour restoration)	$250,000 $265,000*
Rodney	Address river maintenance, flood protection, and impacts of discharges into harbours and rivers through methods such as catchment management plans, flood protection works and stormwater infrastructure	$2,026,000
Upper Harbour	Restore upper harbour tidal flows (Herald Island causeway)	$20,000 for initial scoping study
Waitakere Ranges	Maintenance of existing Twin Streams networks Development of new Project Twin Streams projects Establishment of Manukau Harbour Forum, with focus on improving water quality	$870,000 $1,500,000 Within current budgets
Whau	Whau River Community engagement stream programmes Support Manukau Harbour Forum	$500,000** Within current budget

* The estimated timing for this project is up to 15 years. ** Annually

It is acknowledged that mangrove removal in areas where their growth has accelerated deals with the symptoms of a larger problem of sediment entering estuaries, shallow harbours and the coastal/marine environment. Sedimentation is a natural process in the formation of saltwater lakes and wetlands. However, land use and disturbance have sped up these sedimentation processes resulting in disruption to habitats and displacement of ecosystems. The question for policy makers is how best to address the issue of mangrove management in the context of a broader catchment management process. With limited budgets and financial pressures, the effectiveness of expenditure on restoration projects and investment into natural capital requires clarification. Requests for mangrove removal have come from Auckland communities through the Local Boards, with requests to Council to fund such projects. The question that should be asked is not how to choose between estuarine mangrove management *or* riparian restoration projects.Rather what combination of environmental management instruments can be combined to achieve multiple Council objectives in the 'least cost' way? Time lags are important for understanding why this combined approach is necessary. Riparian planting will slow down sedimentation, but this could take decades to take effect. Mangrove removal is akin to an end-of-pipeline solution, potentially with ongoing costs associated with removal. Removal of mangroves may only be a temporary 'fix' if the catchment and sedimentation processes remain unchanged. The Auckland Plan sets the strategic direction for moving toward integrated management of catchments recognising that human activity is inextricably linked to the natural environment in a systemic way. Integrated management requires assessment of multiple effects, rather than focusing on singular outcomes. This makes decision making multifarious and poses challenges for assessment tools, both theoretically and practically.

1.1 Purpose

This report explores the appropriate use of economic tools for decision making in a complex policy context. Cost benefit analysis is the considered 'rational choice' approach to decision making. There are methodological limitations with this approach, which are considered and explored in the context of taking decisions related to integrated catchment management and estuarine restoration. The purpose of this report is to advise on the choice of a cost-benefit analysis methodology or alternatives.

Cost-benefit analysis is a method to inform decision making, by comparing at least two alternative scenarios/courses of action according to the likely benefits and likely costs that would materialise. Intuitively, all decisions – policy making included – involve the weighing up of costs and benefits and making an informed choice thereafter. Usually the choice with the greatest net benefits is chosen, akin to a *Pareto* improvement in welfare economics[3].

Cost benefit analysis is a central evaluation tool in the New Zealand local government context. It is prescribed in the Resource Management Act. However, a local authority is required to undertake due diligence in terms of expenditure on information gathering for decisions. This report sets out how a cost benefit analysis would ideally be undertaken, with regard to mangrove management as a component of integrated catchment management. The report distinguishes between: a) the development of decision tools and theoretical models; b) research and techniques of measurement; and c) the operational use of measurement within economics. The economic issues are different for all three, ranging from the philosophical to the pragmatic. The biggest problem in undertaking a cost benefit analysis is typically the lack of sufficiently accurate data to populate a cost benefit analysis. Undertaking a cost benefit study, particularly monetising the expected effects, requires the conversion of non-market values into dollar terms. Value sets accorded to environmental goods and services can be difficult to articulate, let alone quantify or monetise, leading to the risk of serious error (due to partial or simple omission due to valuation difficulties) in cost benefit ratios. Furthermore, the benefits of integrated environmental projects are often difficult to monetise and incorporate in a comparable manner.

Nevertheless, this report will show that to *inform* policy decisions (Section 2), cost benefit analysis (Section 3) is an important means of articulating value sets, and identifying key deficiencies in the understanding of a particular policy issue. The methodology outlined in Section 4 is robust enough for a full assessment of the likely effects of introducing integrated catchment and restoration projects. It does require significant time and resource to undertake. Undertaking a full cost benefit analysis would require agreement from the project stakeholders as to the likely outcomes, and how they would be achieved. Such details are not readily available at present. Cost estimates associated with mangrove

[3] This is a situation that makes at least one person better off without making another person worse off.

management and riparian restoration projects from projects undertaken to date in Auckland and New Zealand are presented, where data is available. The management of each catchment is unique, given the complexity of factors that affect the condition of the freshwater system and estuarine receiving environment. Nevertheless, lessons can be learned from these other studies (Box 2).

Box 2 Lessons from past restoration projects

After reviewing numerous studies on (freshwater) restoration projects for the Waikato River Independent Scoping Study, NIWA (2010) made the general observations that:

1. Restoration is expensive – restoration projects on a catchment scale can typically require budgets of many millions of dollars.
2. Restoration is long term – it may be several decades before significant restoration is achieved.
3. Collaboration is needed – restoration often requires participation, co-operation and collaboration from many parties including state and local government agencies, industry, researchers and representatives of indigenous groups, environmental care groups, and the wider community.
4. Build on existing initiatives – attempts should be made to build on existing restoration and environmental management and monitoring activities.
5. Defining the intended outcome(s) is required, which highlights the importance of setting agreed objectives in order to ensure that all partners are committed to achieving these.
6. Successful restoration relies on incorporating traditional knowledge and science. Scientific input must incorporate multi- and inter-disciplinary approaches (e.g., drawing on physical, chemical, geomorphological and ecological expertise).
7. Careful monitoring of restoration activities is required, including tracking expenditure and progress.
8. Adaptive management is required due to the unreliability of predicting outcomes in complex situations.
9. Outreach is required – good communication of project information, objectives, and planned actions should be available to all stakeholders and involved communities.
10. Plan for the future – restoration projects typically involve long timeframes, outside of political cycles.

Source: NIWA, 2010

1.2 Content and Structure

This report critically assesses the use of cost benefit analysis in environmental decision making. The report was compiled from a review of the existing technical and policy documents relating to mangroves; an extensive literature review on decision support tools in economics, particularly cost benefit analysis; and discussions with Council staff in Auckland and the Upper North Island who work on mangrove management.

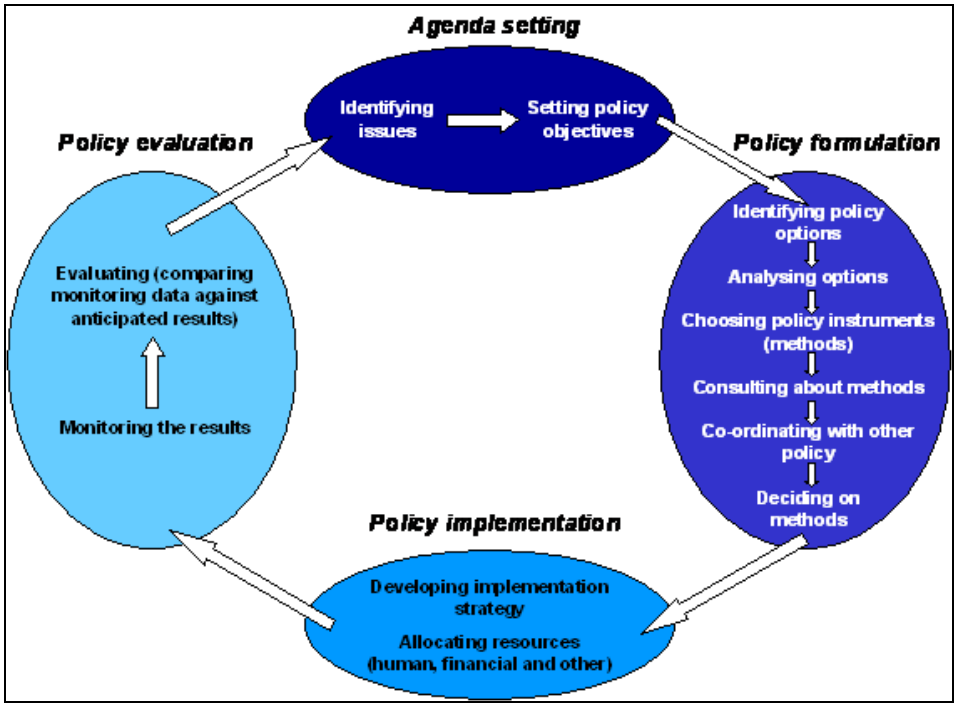
Section 2 looks at decision making in a political context, which seems somewhat trivial, but is central to the choice of decision tools. Rational choice theory, the basis for cost benefit analysis, is at the root of decision theory, so both are critically appraised. Section 3 looks at the theory of cost benefit analysis, and the principles underpinning it. Section 4 establishes a stylised methodology of how a cost benefit analysis would be undertaken to assess whether Council should intervene in a particular catchment. This is followed by a critical discussion of its application in Section 5.

An attempt has been made to use relevant examples and short case studies to illustrate the arguments throughout the report.

2.0 Decision Making

Rational choice theory is the main paradigm underpinning formal models of economic behavior. At its core, it has a cost benefit principle: individuals act as if they were balancing costs against benefits so that they maximise their personal advantage (Friedman, 1953). The decision making process is seen to be characterised by these rational choice laws. Collective decisions are taken through the policy process and the policy cycle has been formulated to typify the rationality present in policy.The policy cycle is a continuous process of problem identification, collecting and integrating information, identifying desirable outcomes, policy development, decision making, implementing the policy change, monitoring effects, policy evaluation and subsequent modification of policy (Laswell, 1951), depicted in Figure 1.

Figure 1 The Policy Cycle



Source: Ministry for the Environment, 2003

The public policy cycle is accepted as a rational approach to policy making. It is a staged model, with each stage considered temporally and functionally distinct. The stages include:

1. Agenda setting which involves the identification of a problem, or understanding that policy intervention is required alongside setting policy objectives;
2. Policy formulation requiring strategic thinking on policy options and methods, consultation on the process, analysis of policy options and assessment of the likely effects of policy;
3. Implementation of the policy;
4. Continual assessment of the policy and monitoring the changes brought about; and
5. Amendment of policy in light of policy evaluation, closing the final loop in the policy cycle. Evaluation is a strategic process of understanding how things can be improved, and often coincides with the first step of problem identification, hence the policy process is cyclical.

Without stating the obvious, assessing at which point of the policy making process the Auckland Council is currently at with regards to mangrove management is important for the choice of decision support tools – in this case cost benefit analysis is being considered. After reviewing Planning documents, Council reports, Technical Papers regarding mangrove, sedimentation, freshwater and estuarine environments it is clear that the Council understands the context within which the management of mangroves should be conducted (Box 3). What is also clear is the complexity of contributing factors in each catchment, leading to sedimentation and mangrove expansion. Therefore land and coastal policies are integrated: mangrove management cannot be dealt with in isolation, but needs to be understood within a broader context of the activities on land and policies relating to freshwater management.

Box 3: Plan Change 4 Mangrove Management – cost benefit underpinnings

Plan Change 4 – Mangrove Management – became operational in the Auckland Regional Plan: Coastal in March 2011. It is underpinned by cost benefit considerations, albeit qualitatively. The recognition that mangroves may adversely affect use and value of the coast in areas outside of Coastal Protection Area 1 indicates that the net benefit of mangrove removal could be greater than the benefits that mangrove provide, in particular instances. The ability to control the spread of mangroves, through hand removal of seedlings in areas outside of Coastal Protection Area 1 indicates that the Council has identified that there are areas where there is no additional net benefit of mangrove expansion over mangrove containment in these areas. These are subject to certain conditions as specified in the permitted activity rule. This in effect is recognition of competing value sets associated with the presence of mangroves (Auckland Regional Council, 2004a).

What requires clarification at this point is a precise articulation of the desired goals/intentions for mangroves and their catchments, the level of estuarine and terrestrial restoration that would be pursued and the location of these catchments and the means by which this integrated restoration would proceed. As will be discussed in the following section, cost benefit analysis is appropriate for choosing between discrete alternatives to achieve a *stated outcome*. Rather than undertake a full cost benefit analysis, an elaboration of estimated costs of achieving integrated catchment and estuarine management may be useful for informing the details of Council's budget planning. This addresses issues of affordability.

Policy can take a range of different forms, including non-intervention, regulation, encouragement of voluntary measures, grant aid/subsidisation, as well as direct public service provision. Cost benefit analysis can be used in different capacities in the policy process to justify the creation of policy itself (measuring the cost of policy intervention against non-intervention), as well as for evaluating policy effectiveness (choosing between policy options to achieve stated outcomes).

The policy making process across all Council activities does not necessarily logically follow the stylised policy cycle identified above. An element of *ad hoc*-ism is evident, as issues emerge spontaneously, through democratic processes, through vested interests or through crises that require decisions. Investment decision on all Council expenditure is not taken at one particular point in time[4] and funds get committed if and when the need arises[5]. Not all contingencies can be planned for (given that we are 'bounded rational' or cannot predict the future). A systematic cost benefit analysis of all expenditure decisions across Council expenditure/policy is not undertaken for competing funds (e.g. assessing whether reallocating expenditure from one area to another – for example on recreation activities to air quality - would increase net benefit in the region), although expenditure is re-evaluated annually when setting the Annual Plan. Marginal cost accounting for expenditure across all Council expenditure would require an inordinate amount of information, and would be subject to the measurement problems associated with economic valuation. Justification for expenditure or investment by the Council is made at a particular juncture, and previously committed expenditure is

[4] For example, the 'Master Transportation Plan' for Auckland prepared by the Auckland Regional Planning Authority in 1955 is still being completed, with expenditure committed to it; and legacy projects from the former Auckland Territorial Authorities and Regional Council are being honoured.

[5] For example, Auckland Council's contribution to the Christchurch Mayoral fund after the 2011 earthquake.

not questioned at each new investment proposal. Hence, there is not a rational process of weighing up the costs and benefits of Council expenditure in a systematic manner across all Council activities. This is problematic for undertaking a cost benefit analysis, as invariably the reallocation of expenditure to explicit mangrove management (effectively a new policy initiative) will require switching funding from other budgets or programmes.[6] The opportunity cost of expenditure on mangrove management as opposed to another project (what the money would have been spent on) should be considered also.

Policy making is a process of identifying what should be done, by examining the underlying rationale and effectiveness of policies, whereas policy efficiency is a measure of how things are done. This distinction is important in the context of a request to undertake a cost benefit analysis of management options for mangroves, as effective mangrove management requires an integrated approach of intervention and management on land (in freshwater catchments) and in the estuarine mangrove areas themselves. This broadens the debate to include the land-based benefits and costs of integrated catchment management. Effective mangrove management policy has *multiple objectives* and an array of permutations and action to achieve these objectives.

2.1 Economic Approaches to Decision making

To 'weigh-up' a decision requires consideration of the choices, with the explicit aim of committing to one choice or course of action. Decision making is a process of navigating between alternatives, arriving at a final choice. Decision making within economics has been studied from a range of perspectives: recognition that most decisions are taken subconsciously, as a matter of routine (Lewis, 1969; Favereau and Lazega, 2003); understanding the psychology of cognitive processes in determining how decisions are taken (Mintzberg and Westley, 2001; Kahneman, 2011); to the development of normative theories of how decisions *should* be taken, assuming an underlying logic or rationality. The Rational Choice Framework within the economic discipline takes this latter normative stance on decision making. '*Homo Economicus'* is the central agent, assumed to act rationally in their own self-interest, having the ability to make judgments toward their subjectively defined ends. Two important components of rationality embodied in the rational choice framework are the so called 'self-interest' and 'present-aim' standards. Self-interest suggests that people only consider costs and benefits that accrue to them directly. A methodological problem arises instantly when a rational choice approach is applied to a society or group of individuals – are the costs and benefits of societal decisions simply the sum of individual preferences, or more specifically can individuals take into account and weigh the costs and benefits for society at large, into their personal decision matrix? This requires an inordinate amount of information, on effects and tradeoffs, and also that there is some incentive to act selflessly. Ultimately it highlights the importance of the evaluating agent(s) in a cost benefit analysis: Whose costs and benefits are taken into account? Adler and Posner (2006) sidestep this problem by recognising that some people may have objectively 'bad' preferences[7] and such unrestricted individual preferences should not be considered in a cost benefit analysis of policy. Thus they advocate a 'restricted preference based account of welfare'. This leaves considerable discretion to the evaluator on such an approach, but it is important to point out, as the evaluator does have considerable discretion in a cost benefit study.

Experimentation in behavioural economics challenges the assumption of self-interest. Many people pursue a variety of goals that are not only in self-interest, but can be self-destructive, or on the other hand the goal may be in the greater common interest (altruism). The present aim standard implies the efficient pursuit of a goal at any particular time, regardless of whether the goal makes sense. These standards lead to the somewhat untenable position that any behavior, no matter how bizarre or self-destructive can be 'explained' by assuming a taste/preference for it (Frank, 1998).

[6] There are also indirect economic flow on implications of making different decisions, resulting in economic consequences in the wider economy. Thus, while directly these impacts may be positive under one scenario, the net combined direct, indirect and induced impacts may be negative under the same scenario. Thus, a CBA is often supported by an Economic Impact Assessment.

[7] Use of the term 'bad' in the sense that they are pervasive to society as a whole, for example drug addiction.

2.2 Rational Choice

The issue of rationality is challenged by Kahneman and Tversky (1974), who recognise the importance of heuristics and biases in problem solving techniques, resulting in *irrational* approaches. These can be due to taking shortcuts in cognitive approaches such as inferring things wrongly rather than working things out logically. Hence there is debate and not universal agreement on what rationality actually means. However, rational choice theory uses a specific definition of rationality, to mean that an individual acts as if balancing costs against benefits to arrive at action that maximises personal advantage. It is this approach that will be used within a cost benefit analysis framework. However it is useful to critique some of these base assumptions.

Simon (1955 & 1959) introduced the concept of 'bounded rationality', recognising that there are limits to the amount of information that a person can assimilate at any particular time, to make a decision. A person does not necessarily reach the optimal decision solution, but instead they apply rationality only after having greatly simplified the choices available. Such is the approach of cost benefit analysis – simplifying the positive and negative effects into a common metric and evaluating options based on the aggregate net outcome. It is arguable whether this is the most appropriate means of making policy decisions.

The assumption of a rational decision making process has been questioned given that not all decisions are made using a logical framework. Mintzberg and Westley (2001) characterise three different approaches to making decisions, ranging from rational to active approaches. They are the 'thinking first', 'seeing first' and 'doing first' approaches (Table 2). These are particularly important to consider when taking decisions on mangrove management and broader integrated catchment restoration, particularly as the value sets associated with mangroves (and hence preferential approaches to their management) have elements from all three approaches.

Table 2. Characteristics of the three approaches to making decisions

	"Thinking First"	**"Seeing First"**	**"Doing First"**
Underlying approach	Science based	Aesthetics, visibility	Craft
Useful for	Planning, programming	Visioning, imagining	Venturing, learning
Communication	Verbal	Visual	Visceral
Based upon	Facts	Ideas	Experiences

Mintzberg and Westley, 2001:89

The 'thinking first' approach to making decisions recognises the importance of establishing facts and using state-of-the-art science in a considered way. Applying a 'thinking first' approach to mangroves requires one to consider the role of mangroves within the ecosystem of harbours and estuaries. Research into coastal ecosystems is increasing as is the awareness of co-dependence between coastal and terrestrial systems. Auckland Council is contributing to an 'evidence base' relating to mangroves, along with other Upper North island Regional Councils and research providers such as NIWA, Cawthron and Landcare Research. This research is generating knowledge and enhancing the understanding of the function and complexity of mangroves within the wider environment, enabling a considered approach. Mangrove management is not simply the removal of trees in the intertidal area. It requires management of the sediment that accelerates the rate of growth of mangrove areas and an integrated approach to land based activities affecting estuarine and coastal receiving habitats. The call for mangrove management usually comes from communities that would like their removal due to encroachment on other activities. However, there are some groups that are calling for preservation of mangroves, and both perspectives are valid. The thinking approach will collate these different value sets to understand the complexity of all aspects of the problem.

The 'seeing first' approach to decision making is important in the context of integrated catchment management as it recognises that action may be driven as much by what is seen as by what is thought. The identification of a problem with regards to mangrove management stems largely from the visibility and tangibility of new mangrove stands and forests in the harbours and estuaries, leaving little doubt to local communities about changes that have taken place in their estuaries over time.

Visualisation leads to clear understanding, perhaps more powerful than conceptual explanations. It should also be noted that visualising outcomes is important for choosing between future scenarios, answering questions of 'what would the harbour look like if sediment were controlled?' and 'what form would the coastal area have in 30 years?' Visual presentation of data and information can be a means of communicating knowledge in an efficient manner (e.g. maps of coastlines and harbours). Contingent valuation exercises often use visual images to infer what people would be willing to pay for a landscape (Kerr and Sharp, 2003).

Decision making on a 'doing first' basis is used by pragmatists, when action is taken through experimentation (Weick, 1995). 'Doing' drives thinking, when it incorporates a learning process. Approaching mangrove management from a 'doing' perspective may circumvent the procrastination of decisions characteristic of a 'thinking first' approach, which may require significant information, resources and time. Exploring the extent of illegal removal of mangroves would indicate a 'doing first' approach by some individuals, who act on the problems they face with regards to mangrove encroachment, disregarding the law. Such an approach is not desirable, particularly when there is uncertainty of the cumulative effects of mangrove removal to the ecosystem (Auckland Regional Council, 2010), and the local site specific effects in cleared mangrove areas are ambiguous, particularly in the long term (see Environment Waikato, 2009).

The formation of community and interest groups with a particular mandate for mangrove management also indicates a 'doing first' approach, with communities responding by attempting to influence the democratic process (within the legal framework) through interest group pressure. Communities that coalesce and form interest groups when affected adversely by mangrove stands (e.g. encroachment of mangroves into navigational channels and beaches) react to the immediacy of the problems they face. The 'doing approach' is also important for communities that learn from the actions of others (communities) in similar circumstances, despite uncertainties in outcome. The 'doing first' approach can stimulate 'thinking' in an iterative process – in the context of mangroves this would be the case if policy had to respond to the actions of people, for example addressing the illegal clearing of mangroves.

In reality, decisions are taken using a combination of the three approaches, in an ongoing iterative fashion. It is important in this discussion of cost benefit analysis to acknowledge that the rational 'thinking approach', while being important should be understood alongside 'seeing' and 'doing' approaches, which can be more reactionary. In particular, the importance of the tangible effects, or visualising outcomes may compromise the less tangible effects of action that are not so well seen. Endangered birds such as the Fairy Tern could be adversely affected by the removal of mangroves, yet given that remaining Fairy Tern populations are barely visible, knowledge of their habitats and vulnerability are not widely known across communities. Similarly, the less tangible or less visible effects, such as ecosystem services, may be given a lesser value by people. Taking action or 'doing' something about a problem that a community faces is a pragmatic solution to decision making. It can elevate the issue into political debate, and force the matter onto the decision makers' agenda. In economics a rational balanced 'thinking' approach is usually assumed, particularly for the cost benefit methodology.

3.0 Cost Benefit Analysis

Formal economic cost benefit analysis was initially formulated as a financial management tool (Bringham and Ehrhardt, 2002). It was used for project selection – a project should not be undertaken if the cost exceeded the expected cash flows. When undertaking a cost benefit study for society, the parameters under consideration extend considerably to cover environmental, economic, social and cultural effects. This makes the undertaking of a cost benefit analysis more of a research project to estimate/measure such values, which can be both time consuming and costly. This Section looks at the role of cost benefit analysis in New Zealand local government legislation before detailing the principles of cost benefit analysis.

3.1 Cost Benefit Analysis in a New Zealand policy context

Cost benefit assessment is considered an instrumental valuation tool in local government legislation in New Zealand. The establishment of the Resource Managment Act (RMA) in 1991 formally introduced the obligation for regulators/local authorities in New Zealand to include a 'consideration of alternatives, benefits and costs', laid out in Section 32 of the RMA. Section 32 does not prescribe that costs and benefits should be monetised or even quantified, and in some Environmental Court rulings did not accept that consideration of the matter (being presided over) in monetary terms only was appropriate. Questions arise as to how regulators and decision makers should use cost-benefit analysis in taking their decisions. Quality Planning[8] published recommendations for methods of implementing a Section 32 cost benefit analysis.

The Local Government Act (LGA) 2002 also provides a mandate for cost benefit analysis. Section 77 of the Act advises on consideration of the 'four well-beings' in decision making. It states that all reasonably practicable options for the achievement of the objective of a decision should be identified, while considering the benefits and costs of each option in terms of the present and future social, economic, environmental, and cultural well-being of the district or region. The intention of this clause is clearly to have a broad integrated assessment of the effects of local government decision making, both now and into the future. Rather than pursuing policies that achieve stated objectives, this section mandates the local authority to consider the wider effects of policy and decision making.

Section 79 of the LGA outlines that a local authority should use discretionary judgment about the degree to which benefits and costs are to be quantified and the extent and detail of the information to be considered. Depending on the significance of the decision (e.g. cost, size and duration of project/policy) an appropriate amount of detail to support that decision should be determined by the local authority. Creating an 'evidence-base' for policy is an essential component in the policy process, to make informed decisions, but the question of how much data and information is sufficient to make a decision is at the discretion of the local authority.

This tension regarding decision making in the two main Acts pertaining to local authorities (decisions to be taken using cost-benefit methodology, considering the four well beings, while also using discretion in the amount of detail that is required to support those decisions) has meant that a lot of cost benefit analyses have been descriptive and qualitative, rather than quantitative and fully monetised (Wilson, 2011). Overall within local government and planning decisions, non-monetised approaches to costs and benefits are considered acceptable. This does not overcome the intractible problem of uncertainty over environment effects in particular, given that there may be unintended consequences that are unknown to natural systems.

[8]The Quality Planning Project is a partnership between the New Zealand Planning Institute, the Resource Management Law Association, Local Government New Zealand, the NZ Institute of Surveyors and the Ministry for the Environment.

3.2 Principles of Cost Benefit Analysis

Cost benefit analysis in strict economic terms requires a quantification of what people value – both negative and positive. The quantifiable values are then monetised in dollar terms, so a comparison of relative values is possible. The theoretical foundation of cost benefit analysis rests on benefits being defined as increases in human wellbeing (utility) and costs defined as reductions in human wellbeing (Pearce *et al*., 2006). Some costs and benefits are relatively easy to measure whereas others are not so easy to discern. The issue of valuation is central to a cost benefit accounting system, and economic methods have developed to measure value. Measurement techniques have evolved and are continuously improving[9].

Value is a property of an object, whether physical or abstract, representing that object's degree of importance. However, people in different cultural settings communicate their sense of value in multi-layered ways (O'Connor, 2002 & 2007). Economic valuation has its roots in utilitarianism, expressing the degree to which a good or service satisfies individual (or societal) preferences.

Many goods and services are exchanged on a market, which automatically reveals their value (e.g. the cost of a tree for riparian zones). Market valuation is the price at which an asset or service would trade in a competitive auction setting. This can be used when goods are transacted, and market prices can be used to discern value. Market valuation is appropriate for private goods and services, but problematic for common pool resources and public goods where externalities are usually not included. Economists use methods such as 'hedonic pricing' to decompose a market price into constituent parts. Hedonic pricing is useful for measuring intangibles such as the value of a seascape to the price of a residential house. Another survey based method to reveal the market value of something is to measure the 'willingness to pay' for it. The market is capable of revealing only one component of the total economic value, known as 'direct use' values. Other values include indirect use, and non-use values.

'Indirect use' values are also derived from personal use but as their title suggests they are not traded on the market. They are related to the ecosystem services that are provided by natural resources. For example, if mangroves provide the spawning ground for certain fish species that are not necessarily directly consumed by humans, there is an indirect value. Mangroves are capable of carbon sequestration, which is another ecosystem service. Ecosystem services are often public goods, which means that nobody can be excluded from consuming that good. The problem with public goods is that although people value them, there is no incentive from an individual's perspective to pay to maintain that good. The 'willingness to pay' measures for market goods, described above, is for personal consumption whereas establishing a credible value of public goods through willingness to pay may not be accurate.

Non-use values include bequest values and existence values. Bequest values relate to inter-generational considerations, and the satisfaction gained from preserving the environment for future generations. Existence values result from knowing that a resource or species exists, despite the valuer having no use for the resource.

Cost benefit analysis encompasses both marketed and non-marketed effects. Cost benefit analysis has an objective of using strict valuation methods to derive shadow prices for the non-market values. The key to the (strict) cost benefit approach is monetary reductionism, that is, to reduce all costs and benefits of a project or policy to a dollar, which equals 'net position'. When prices have been identified for market values and non-market values, cost benefit analysis can then help identify the optimal choice from the range of possible resource allocations or scenarios. It is not always possible or feasible to assign monetary values to costs and benefits. For such cases, it is more appropriate to describe the perceived costs and benefits and leave them in qualitative form. These do not fit well into a monetised cost benefit analysis, particularly if a cost benefit ratio is being sought for decision making.

[9] For example see The Economics of Ecosystems and Biodiversity international project for reaching consensus on valuing natural resources. www.teeb.org

Cost benefit analysis, in theory, offers a tidy and simplistic counting framework for solving complex social and environmental problems. Practical implementation of cost benefit analyses for resource allocation was pioneered in the 1950s in the United States, due to concern of overall efficiency in government; although cost benefit frameworks were used as a tool for financial analyses of investment decisions (particularly infrastructure decisions). Rather than measuring expected cash flows in a financial analysis, a market value of the positive benefits from the project/investment are estimated for a policy change on resource use. Arrow *et al.* (1996) wrote a seminal essay discussing the appropriate role for benefit cost analysis in environmental and health policy-making stating:

"Benefit-cost analysis can play a very important role in legislative and regulatory policy debates on improving the environment, health and safety. It can help illustrate the tradeoffs that are inherent in public policymaking as well as make those tradeoffs more transparent. It can also help agencies set regulatory priorities. Benefit-cost analysis should be used to help decision makers reach a decision. Contrary to the views of some, benefit-cost analysis is neither necessary nor sufficient for designing sensible public policy".

Arrow *et al.* (1996) recommended that all benefits and costs of a project should be identified; those that can reliably be monetised should be, uncertainty in the benefits and costs should be calculated and reported, and distributional consequences (who gains and who loses) should be addressed and reported in a benefit cost analysis. Eight principles on the appropriate use of cost benefit analysis were identified (Arrow *et al.*, 1996):

1. Cost benefit analysis can be useful for comparing the favourable and unfavourable effects of policies, as it helps decision makers better understand the implications of decisions. This is done through a visioning process, thinking about the likely effects.
2. Decision makers should consider the economic costs and benefits of different policies in the development of regulation.
3. Cost benefit analysis should be required for all major regulatory decisions. The scale of a cost benefit analysis depends on both the stakes involved and the likelihood that the resulting information will affect the ultimate decision.
4. Decision makers should not be strictly bound by cost benefit tests. Factors other than aggregate economic benefits and costs may be important, such as equity issues or qualitative factors (see point 8 below).
5. Not all impacts can be quantified let alone monetised. Therefore care should be taken to assure that quantitative factors do not dominate in importance.
6. The decision making agency should put the cost benefit analysis out for external review, again to ensure that the visioning process is credible and important factors have not been overlooked.
7. Economic assumptions should be explicitly stated and should be consistent when calculating benefits and costs. This includes factors such as the (social) discount rate.
8. A good cost benefit analysis should identify important distributional consequences for subgroups of the population. Although the cost benefit ratio is calculated at an aggregate level, there might be specific equity issues for certain stakeholders, or the burden of costs may fall disproportionally. As the political process and processing requires balancing trade-offs, the distributional effects of a change in policy is important to understand.

Cost benefit analysis differs from cost effectiveness analysis, which is a more specific method used to measure the achievement of some targeted policy. Cost effectiveness measures the least cost option to achieve a stated outcome.

The following section describes how a cost benefit analysis could be undertaken by the Auckland Council. It identifies (qualitatively) the costs and benefits associated with integrated catchment restoration/improvement projects, and mangrove removal would be a component of the larger catchment project. Further work is required to find values for these for each catchment under consideration.

4.0 Methodology for a Cost Benefit Analysis on Integrated Catchment Management

This section outlines the ideal approach that would be applied to a cost benefit study, if there were no limitations in terms of data or knowledge gaps. Assessing catchment restoration including mangrove management requires a measurement system that moves beyond the concept of private costs to cost accounting for society. Establishing this methodology is a useful exercise to assess gaps in knowledge and identify any measurement constraints. Table 3 sets out the framework for undertaking a cost benefit analysis on integrated catchment management projects.

The introduction of restoration projects/integrated catchment management would have set goals and intended consequences/effects. These would be articulated in the form of 'scenarios' and the cost benefit analysis would be an *ex ante* assessment (prior to realising the effects). The process of establishing scenarios through mental models and envisaging expected outcomes is a long established 'causal-inference' method in the social sciences (Weber, 1905). This is an integral component of cost benefit analysis, as it is the marginal change that is measured, or the net effect brought about by a change in policy over and above what would likely happen given the *status quo*. This method is presented as a stepped approach, described below.

Table 3 Framework for Developing Cost Benefit Analysis

SCENARIOS: course of action and likely effects	LIST OF COSTS AND BENEFITS including who bears them and when	METHODS: Valuation techniques (How to measure costs and benefits)	ASSUMPTIONS (Method, limitations and caveats)	MEASUREMENT (Implementation)
What to measure? Scenarios – Envisioning the likely effects brought about by a change in mangrove management. Scientific expertise on each individual catchment/estuary required.	Economic Social Cultural Environmental	a) Is it possible to observe, infer causality and therefore measure the phenomena? b) Establish metrics - market valuation techniques? c) Non-market valuation (Willingness to pay, Willingness to accept) d) No feasible method for valuation (in this case use a qualitative assessment/ description of consequence)	* Assessment of data availability * Timeframes included *Social discount rate used	* Valuation *Check for double counting * Sensitivity analysis (Low/Medium/High) * Uncertainty in project effects

4.1 The Steps

Step 1 – Establishing the *Status Quo*

The first step is to develop and articulate a scenario for the *status quo* for each area where mangrove management and/or integrated catchment management is under consideration. The scenarios should be undertaken at a local estuary/harbour or catchment level, given community aspirations/demand and within the existing regulations.[10] A review of the Auckland Council Local Board Plans for 2011 indicates which local boards have prioritised active mangrove management, and these were presented in Table 1. These catchments/project should be considered in the first instance.

The causal processes that are shaping the coastal environment, within which mangroves grow, are complex and dependent on the physical, hydrological and geographical attributes of the area, in addition to the human impact from land based activities and the rules pertaining to mangrove management (Townsend and Thrush, 2010; Hayward and Morley, 2005; Morrisey *et al.,* 2007; Peart, 2007). From reviewing the existing literature on the state of knowledge of freshwater catchments and coastal receiving environments, it is clear that each catchment is unique. Establishing the *status quo* is by no means an easy task, given the uncertainties, complexities and interconnectedness of the land and coastal systems. Considerable work was undertaken to establish the future changes of mangrove habitat for the east coast estuaries in Auckland (Swales, *et al*., 2008). Further uncertainties are introduced by the projections for the concept of 'squeezing-out' of mangroves by sea level rise in the Auckland Council area (Morrisey *et al.* 2007). It is likely that man-made infrastructure (sea walls) will be built to protect the existing infrastructure from projected sea-level rises, which would prevent mangroves from naturally colonising the would-be intertidal areas behind tghe built sea-protection. Establishing the *status quo* requires evaluating a range of attributes including current land use, past land use along with geological and hydrological features.

The status quo scenario should include the current rates of sedimentation loading in the estuaries/receiving coastal environment. The time lags between land disturbance and sediment reaching and settling in harbours may be significant (Swales *et al.,* 2008). Consideration should be given to recent activities on the land, both positive and negative.

The deposition of estuarine sediment may result from hydrological wave action (i.e. not directly from streams adjoining the sediment deposits). This may be of relevance to the larger harbours with many streams in the catchment (Morrissey *et al*, 2007), as the control of sediment on a particular stream may not benefit the coastal area directly contiguous to that stream.

An assessment of the ecology of the catchment should be undertaken, to establish the current state of the streams and estuary.

Understanding and communicating these processes to the community is important. Establishing the *status quo* requires technical input from ecologists, hydrologists and catchment scientists. The status quo should include a well-informed appraisal of the likely outcomes, without further intervention. There will be uncertainties in establishing the *status quo* scenario, which should be listed.

[10] The areas where mangrove removal would be permitted (under resource management consent) are specified in the Auckland Regional Plan: Coastal Chapter 16. They include areas within designated Coastal Protection Area 1, where mangrove colonisation would adversely affect wading birds and roosting areas, and in areas where mangrove expansion may affect maintenance and use of existing structures and the functioning of drainage systems, or where there is a wider environmental, community or public interest.

Step 2 – Developing scenarios of likely effects with active management programmes

The second step involves the development of a management plan for each estuary/catchment or area where mangroves are actively managed. A management plan sets out the intended intervention or action for each catchment/harbour, envisioning the outcomes, and can be used for comparing against the *status quo*. It is recommended that at least two alternative scenarios to the status quo should be created, but it may be prudent to develop more, to show various options and to compare the relative effects of different approaches. For riparian planting, an example could be the difference between having a 5m wide riparian zone to a 10m wide zone, or the difference between type of fence used to keep stock out of waterways, or the partial planting of steep banks rather than the entire stream. In estuarine areas the scenarios could explore the likely effects of whole mangrove tree and root removal versus above ground/water cutting and removal.

These scenarios could include a 'gold-plated' full integrated approach to catchment restoration[11], including riparian planting, sediment loss minimisation, and disturbance control, mangrove removal, marsh restoration, channel dredging, or it could include 'partial' management options within the estuarine area (e.g. mangrove and sediment removal, engineering works on channels etc.), or even a 'minimalist' scenario (of just mangrove removal with no further riparian restoration work) to explore and compare likely effects.

Establishing these scenarios requires a fluid exchange between the community and scientific experts (including hydrologists, ecologists, arborists, engineers etc.) to share local information, discuss experiences from similar mangrove management projects and design a process that will meet the needs of the community in that particular catchment. The assessment of scenarios needs to be done on a case-by-case basis, given the complexities of the natural systems and the interaction/impact of human activities. The timing of effects brought about by intervention should be estimated, given the immediacy of the demand for the removal of mangroves by communities where their infrastructure, navigational and recreational opportunities are being compromised by the spread of mangroves. In comparison, the time required for sediment control through riparian management is much longer[12] – so the effects materialise in the future.

It is likely that to address the management of mangroves, the health of harbours and freshwater catchments, a combination of actions would be undertaken. It is not a question of whether action should be taken either in the estuarine areas (e.g. selective mangrove removal) *or* on land for sediment control, but it would require a mixture of both. An assessment would also need to be made over the extent of riparian planting, or targeting sensitive areas, or areas that have the greatest potential for impact. Each scenario would exist independent of the others, enabling the costs and effectiveness of the actions to be determined.

Intended use of voluntary labour/existing environmental groups and local community for activities such as mangrove removal and riparian planting should be specified, as these will impact on the costs of the intervention and the likely success of the action. Consideration of the levels of community engagement should be included in the scenario, including liaising with landowners, using existing community groups including iwi, schools and environmental organisations. The choice of management approach will have a significant implication on the costs involved. For example, if voluntary community labour is used, this will be a significant cost saving and could have positive social benefits in terms of galvanising a local community – people meeting each other, taking pride in their local environment. However voluntary labour may require training, especially in areas with

[11] This is described by Currie *et al.* (2009) as when the goal is to set the ecosystem on a trajectory toward a pre-disturbance condition, which is self-regulating and integrated into the relevant ecological landscape. This is usually not feasible.

[12] For example, five years is generally accepted as the length of time for riparian zones to stabilise soil, while it is not possible to accurately define the levels of sediment that might occur naturally because at any one time, naturally occurring levels of sediment will vary in response to a wide array of unpredictable influences operating within the catchment (Auckland Regional Council, 2001b).

cultural or ecological sensitivities[13]. Clear articulation of the management approach should minimise the risk of unintended consequences of any action undertaken, and to ensure that all costs and benefits are conceived at this point, to the best of knowledge.

The scenarios should detail the extent of mangrove management/removal; how the mangroves would be managed e.g. by machinery or hand and who would undertake these processes (contractors or community); the extent of removal, either cut down at base or whether the roots would be removed; what would be done with the cut down trees – removed off site or mulched in the estuary. In the case of mangrove removal in the Pahurehure Inlet, helicopters were used to remove the mangroves from the site, given the restrictions on use of heavy machinery as per the consent. This increased the costs significantly.

If the scenario includes integrated catchment management, the extent of managing the wetlands/freshwater network into the estuary should also be included. Consideration of the size and extent of riparian zones should be articulated. The choice of plants and/or trees will affect the ensuing costs and timeframes for benefits (sediment reduction) to be realised (e.g. harakeke/flax is a cheaper plant than trees and quicker to establish and mature, whereas the root system of trees may be required for bank stabilisation). Any plans for sourcing materials used for riparian restoration projects should be detailed, such as community nurseries for plants and trees; or the intended use and type of fences, if appropriate for those streams. The extent of riparian planting (e.g. kilometres) and type of freshwater habitats being managed (e.g. steep hill country, forestry land, dairy or horticultural) will have an effect on the rate of sedimentation loss.

The likely outcomes of each scenario should also be specified at this point. This process would require the input and integration of significant technical expertise, including the likely effects (many of which are still unknown) on the mid to long term effects of mangrove removal with and without root removal, effects of sediment dispersal in the larger coastal receiving environment if natural flushing occurs. Studies have been undertaken in the Auckland region relating to aspects of these effects, but what is clear from these studies is that such assessments are required on an individual or localised basis for each estuary and corresponding catchment, to understand the hydrological processes of streams and estuary, rate of sedimentation, extent of mangrove growth/spread.

Importantly the timing of the effects should be considered, to ensure that expectations are realistic and to recognise that there may be time-lags present (e.g. the flushing of sediment from the estuary). The likelihood and extent of ongoing management should be outlined, to enable a scheduling of future costs.

Step 3 – Identification of Costs and Benefits

After undertaking the scenario building process, including a management plan for the catchment, the costs to implement the plan and the benefits of the outcome should be identified. It is the difference between what is anticipated by the *status quo* ('without' active management/restoration projects) and the 'with' scenarios that should be identified in this step. This is particularly important for benefits – as it is not intended to identify the benefits of the ecosystem in itself in total, but the benefits brought about by the actions undertaken in the scenarios. Another important point to consider regarding benefits relate to the concerted action of the different individual projects. As the estuarine receiving environments depend on the network of streams that feed into it, environmental improvements need to be measured on different scales: health of freshwater streams and estuarine level. An integrated catchment restoration project links the upland, lowland, freshwater and coastal habitats, and there are costs and benefits associated with both terrestrial and coastal intervention. This method explicitly separates these two scales for clarity.

Tables 4 and 5 displays the costs and benefits identified from reviewing other studies on integrated catchment management and mangrove removal programmes undertaken in New Zealand to date (EBG *et al*., 2012; Market Economics, 2011; NIWA, 2010; Auckland Regional Council, 2001). These costs and benefits of the four well beings should be considered: economic, social, environmental and

[13] Community volunteers hand cut mature mangroves at the base of the tree in Wharekawa Harbour, Waikato. Considerable care had to be taken to protect the sea grass that was present – e.g. the roots of the mangroves were not extracted.

cultural. Establishing who (individuals or groups) bears the costs and receives benefits should be included, for equity considerations. Cost benefit analysis for local authorities and democratically elected organisations requires a measurement system that moves beyond the concept of private costs, to looking at costs for society. Implicit in this is the trade-off between costs and benefits, and the ability to identify winners and losers in this process.

Table 4 Summary of costs and benefits associated with estuarine restoration

Cost	Benefit
Economic Consent costs Technical expertise for management plans Labour/contracting costs (mangrove removal) Dredging/sediment control	**Economic** Increase in coastal land values Protection of existing infrastructure (e.g. boat ramps, drains) Improving fish stocks
Social Conflict (if contested values within community regarding mangrove removal)	**Social** Amenity and recreational opportunities Social capital formation with formalised voluntary environmental/restoration groups Legacy/Bequest of integral ecosystem to future generations
Environmental* Loss of ecosystem benefits of mangrove removal (e.g. carbon sequestration) Sediment dispersal to other estuarine areas (if root system of mangroves removed)	**Environmental** Restoration of sandy benthic habitats with increased biodiversity Increased biodiversity (harbourwide)
Cultural None identified	**Cultural** Move toward managing taonga in an integrative manner Restoring the mauri of ancestral water Restoration of taiapure Potential mobilisation of urban Maori (those living outside their Rohe) into restoration projects

* The environmental costs associated with removing mangrove have been considered by the Auckland Council in the Auckland Regional Plan: Coastal. As mangrove removal is permissible with appropriate resource consent, it can be assumed that an initial screening of the environmental costs of mangrove removal have been factored in, if removal is under consideration in the areas where it would be permissible. The consenting process would have filtered out/accounted for such cost (e.g. in coastal protected areas, the costs of removal are considered exponentially higher than the benefits that would be obtained, given the current rule set in the Auckland Regional Plan. It should be noted however that there is uncertainty in environmental effect, which in turn affects the valuation process.

Table 5 Summary of Costs and Benefits for fencing and riparian management in freshwater catchments

Cost	Benefit
Economic Fencing materials e.g. 3 string or post and batten fences Construction of alternative drinking stations on farms Native plants and trees Productive land lost, calculated by farm type (e.g. dairy, sheep and beef, horticulture). Technical expertise and developing management plans Invasive freshwater plant control Rubbish/debris removal Wetland and marshland restoration Construction of fish passages Labour/contracting costs	**Economic** Increases in land values and aesthetics Increase in stock health (reduction of stock loss in waterways, shade and clean water provision, pasture edge planting of medicinal plants for livestock e.g. harakeke for intestinal worm control) Production of marketable products (e.g. carbon credits, harvestable products such as maanuka for honey production) Marketing opportunities on environmental grounds Indirect benefits in contributing industries
Social Extension activity and marketing of project to private land owners Volunteer's time Landowner resistance to change Division in community over distribution of benefits	**Social** Social capital formation with formalised voluntary environmental/restoration groups Partnerships between Council, iwi, landowners, communities and stakeholders Enhanced sense of place and local environmental stewardship 'Outdoor classroom' for local schools and environmental awareness (social learning) Amenity values Recreational opportunities Legacy/Bequest of integral ecosystem to future generations
Environmental None identified	**Environmental** Provision of habitat (ecological corridors) and food for aquatic life, bird and terrestrial species Reduction in sedimentation losses (approx. 230 tonne/km2/year lost if forest cover removed) Estuarine hydraulics stabilisation through sediment reduction (acknowledging time lags for this benefit to be realised) Improved water quality - reduction of nitrogen, phosphorous and faecal discharge to the water Improved turbidity and water temperature Increased hydraulic efficiency in streams, reducing flooding Wind breaks during extreme weather.
Cultural None identified	**Cultural** Move toward managing taonga in an integrative manner Restoring the mauri of ancestral water Restoration of mahingakai and traditional medicine plant resources Traditional art and craft resources

Any changes from the status quo would be classified into costs (e.g. labour, contracting costs, materials, training, community meetings/extension, loss of productive land, compliance etc.) and benefits (e.g. habitat restoration of land and estuary, biological diversity, navigational access, recreational opportunities, community building, increase in land value, increase in stock health).

The likely timing of costs and benefits should also be established, given that there will inevitably be a time-lag between when expenditure is made on catchment management and when the benefits are realised – often decades later.

As can be seen from the case studies in the boxes 5-8, the costs are highly variable according to each catchment. Management techniques chosen and the use of various technologies can impact on the costs.

Step 4 – Measurement of Costs and Benefits

The fourth step is perhaps the most challenging component, the method to measure the costs and benefits of the change *brought about* from the intervention, as articulated in the scenario. The measurement and valuation of environmental, ecological[14] and social costs and benefits can be difficult.

A process for selecting the methods and establishing how to measure is required. Therefore measurement tools need to be selected. Each cost and benefit should be assessed as to whether market valuation techniques are possible – for many of the costs of mangrove management, estuarine capital works, riparian planting, labour costs and compliance costs, market valuation techniques are possible. For other costs such as habitat change that occurs due to the management process (e.g. valuing sandy benthic environments over mangrove habitats), the costs and trade-offs may not be so easily measured or monetised. An assessment of whether to use non-market valuation studies for measuring benefits (see box 4 and 5 for like studies) should be undertaken (willingness to pay for restoration, willingness to accept etc.), while bearing in mind the cost of obtaining such information.

Prior to attempting to measure all costs and benefits, it may be prudent to undertake an 'analytical hierarchy process' (Saaty, 1980 & 2008), as a formal method for ranking and focusing the decision makers (and perhaps the experts and valuators) on the perceived relative importance of the identified costs and benefits, for example decisions over whether carbon sequestration costs should be measured if mangrove removal in the coastal environment is offset by riparian planting in the catchment. The analytical hierarchical process method is often used within multi-criteria analysis.[15] Here it could be used as a pragmatic approach if resources are unavailable to undertake a complete valuation process on all costs and benefits.

Given that some benefits will only be realised at a future date, it is difficult to assess the social benefits for the next generation(s), assigning perceived estimates of their value sets, in a world which we know will be different to ours, but have little understanding of. Hence a discount rate is used to convert the flows of cost and benefits over time into a net present value (Young, 2001). Discounting is applied in cost benefit studies as people generally prefer to receive benefits sooner rather than later. Also, there is an opportunity cost to money. Money that is available now is worth more to people than money received in the future.

Some of the direct costs of restoration projects are readily available from other projects that have been undertaken in New Zealand (e.g. riparian fencing and planting, engineering solutions to dredging). Similarly the opportunity cost of productive land that gets converted into riparian zones (e.g. reduced stocking density resulting in reduced productivity) can be calculated from farm models (NIWA 2010). The valuation of habitats and ecosystems is more difficult, dependent on the state that

[14] The Economics of Ecosystems and Biodiversity (TEEB) is an international initiative to draw attention to global economic benefits of biodiversity, and in particular to set global standards for natural capital accounting.

[15] It is appropriate in multi criteria analysis where pairwise comparisons between the criteria are made. The question of 'how important is A relative to B' is posed, and the ranking can be codified on an intensity scale (such as equally important, moderately more important, strongly more important).

the system is in and the ecosystem functions it performs. The 'benefits-transfer' method uses existing monetary evaluations of environmental values on one site to estimate the environmental values in another site, with similar settings. This method is normally used for scaling up for global estimates rather than across sites (Turner *et al*, 2003; Costanza *et al*, 1999).

If there is no feasible mechanism to measure the costs and benefits a decision as to how to proceed needs to be taken, whether the information is left in a qualitative form, and a sensitivity analysis is undertaken to the costs and benefits, given the inability to include monetised values for all costs and benefits.

The main consideration in this step is to check the availability of data and the likely costs of obtaining any missing data. The following boxes provide examples of how some of the costs and benefits have been measured in previous studies.

Box 4 How much do Aucklanders value healthy coastal ecosystems?

A choice model experiment, looking at community preferences for the coastal marine environment, was undertaken as part of Auckland's stormwater research (Batstone and Sinner, 2010). This approach used a survey to get respondents to reveal their preferences for the state of the coastal ecosystem, using pictures/visual images to denote the environmental quality attributes of the coastal system. It asked the respondents how much they would be willing to pay for improvements to quality. This study showed that Aucklanders revealed a preference for outer coastal beaches over upper and middle harbor zones. The choice experiment was focused on environmental quality that is affected by stormwater – ecological health, water clarity and underfoot conditions. The study showed that Aucklanders would be willing to pay in the order of $1.15 billion in remediation works and policy changes to improve outer zone ecological health from low to medium quality.

A similar approach could be undertaken for a cost benefit analysis on integrated catchment management. What should be made clear in such a study is what *values* are taken into account – the recreational use of the harbor/coastal areas and streams, the ecological integrity of the catchment etc. to ensure that values are not captured more than once.

Box 5 Valuing the quality of streams

A choice modeling experiment was applied to two different streams in two areas of Auckland, in Manukau City and in North Shore City (Kerr and Sharp, 2003). The aim of this study was to provide estimates of community preferences for differing states of streams and the value attached to these alternative states. The study looked at a number of different attributes of stream health, and found out how much each household would be willing to pay for improvements in the particular attribute (part-worth). The attributes of value were: water quality, native fish species, fish habitat, moderate streamside vegetation, plentiful streamside vegetation and channel (for degraded streams). Results show that people place significant values on water clarity, channel form and numbers of native fish species, and the study showed dollar figures for each attribute.

The study explored the possibility of using a 'benefits transfer' method to use survey results from one site onto another (i.e. ability to scale the values for the two streams to all streams in the region). However, the statistical errors were high, and the authors counsel against using benefits transfer.

The study also found that the personal attributes that significantly affected choices were: age, university degree, sex, number of people in the household, home ownership, Maori ethnicity, household income over $50,000, household income over $100,000, North Shore or Manukau City resident and interview or postal survey.

Box 6 Estimates of riparian planting and fencing costs by farm type – Waikato Scoping Study

A comprehensive *ex post* assessment of the cost of restoring the Waikato River to its previous health was undertaken under the terms of the Treaty Settlement (NIWA, 2010). The report contains useful figures for capital expenditures, and likely sediment reductions per farm type brought about by riparian planting. The table below shows the estimated costs for riparian planting and fencing.

Cost used in cost abatement calculations for the Waikato River Independent Scoping Study

Description of action	Costs	Comments
5 m wide native revegetation buffer for **dry stock** farm streams currently having grass riparian vegetation	**$58,000**/km for post and batten fences ($18/m = $36,000/km stream) + 8 troughs ($250 ea) per km stream + native grad plants @ 2,500 stems/ha ($5 planted) + maintenance to year 3 ($8,000/ha)	Minimum width buffers for aesthetics requiring more ongoing vegetation maintenance and weeding than 10m wide buffers. Post and batten fences needed to exclude sheep.
5 m wide native revegetation buffer for **dairy** farm streams currently having grass riparian vegetation	**$32,000**/km for 3 wire electric fences ($5/m = $10,000/km stream) + 8 troughs ($250 ea) per km stream + native grade plants @ 2,500 stems/ha ($5 planted) + maintenance to year 3 ($8,000/ha)	Minimum width buffers for aesthetics requiring more ongoing vegetation maintenance and weeding than 10m wide buffers. Electric fences needed to exclude cows.
10 m wide native revegetation buffer for **dry stock** farm streams currently having grass riparian vegetation	**$79,000**/km for post and batten fences ($18/m = $36,000/km stream) + 8 troughs ($250 ea) per km stream + native grad plants @ 2,500 stems/ha ($5 planted) + maintenance to year 3 ($8,000/ha)	Optimal compromise width buffers for aesthetics. Post and batten fences needed to exclude sheep. Wider buffers particularly beneficial on larger streams.
10 m wide native revegetation buffer for **dairy** farm streams currently having grass riparian vegetation	**$53,000**/km for 3 wire electric fences ($5/m = $10,000/km stream) + 8 troughs ($250 ea) per km stream + native grade plants @ 2,500 stems/ha ($5 planted) + maintenance to year 3 ($8,000/ha)	Optimal compromise width buffers for aesthetics. Post and batten fences needed to exclude cows. Wider buffers particularly beneficial on larger streams.
Willow removal then fencing and native revegetation	**+$14,000**/km along 1st-2nd order streams or **+$24,000**/km along > 3rd order streams	Willow removal is cheaper per km along small streams where machinery can operate from one bank

Box 7 Whaingaroa Harbour Care Society

In the Waikato region, a community programme of harbour restoration began in 1995, with the establishment of the Whaingaroa Harbour Care Society. The project is an example of integrated catchment management with multiple environmental objectives, primarily enhancing the quality of water entering the harbour but also increasing water quality of the Wainui stream, reducing sediment in the harbour, erosion control and soil stabilisation on the land, and inadvertently stock health on the farm land and environmental stewardship.

Initially the planting of riparian margins were on the Wainui stream, from Mt. Kapioi to Whaingaroa Harbour (in order to use as a demonstration site), but the group is now focusing on harbour and stream margins elsewhere in the catchment, including Waingaro, Waitetuna and Ohautira streams. The catchment of the whole Whaingaroa Harbour covers 525km^2. It was estimated that streams in the catchment with a cover of indigenous forest generate about 45 t/km^2/yr of sediment, whereas if this forest cover is removed, as in pastoral catchments, this can increase to 230 t/km^2/yr – over five times the amount of sediment loss.

The Whaingaroa Harbour Care Society was driven mostly by people who were not substantial landowners in the catchment, and management of the problem required a collaboration of landowners, who were initially not completely willing to fence off streams and harbour margins, and plant riparian margins. The group formed a part of the 'Wainui Farm Committee' along with tangatawhenua and community members and concentrated on showcasing the fencing and planting of the Wainui reserve farm. The plant nursery is a functional business, selling plants and trees to farmers. The selling of the plants (at a nominal price) was intentional, as it placed a dollar value on the plants, rather than being given for free, with potentially no value attached. Waikato Regional Council contributes to the cost of fencing materials, while the Whaingaroa Harbour Care Society has a nursery for the plants. Harakeke (flax) is the main species planted, but others including cabbage tree, manuka and karamu were also used. Harakeke is relatively easy to produce (from seed or by splitting parent bushes), and it is recognized as being a multifunctional native plant with a wide tolerance range.
The Whaingaroa Harbour Care Society does not have a specific mangrove control objective, but the case study provides an example of how sediment can be reduced/controlled over longer timeframes.

Box 8 Tairua: mangrove removal proposed costs

A Harbour and Catchment Management was developed in Tairua on the Coromandel (March 2012). A strong demand to remove mangroves in the Tairua Harbour was expressed by local communities. It is proposed to remove between 20 to 25 hectares of mangrove cover. The estimated total cost to go through the consenting process, mangrove removal and ongoing mangrove seedling removal is over $700,000 over a 10-year period. The estimated costs include:

$91,000 preparation of application – assessment of environmental effects, technical information, public consultation.
$140,000 Consent processing – depending on whether a hearing is needed
$160,000 Mature mangrove removal
$90,000 Seedling removal
$125,000 Mitigation, compliance and monitoring
$120,000 Management and reporting

The figures above are just for mangrove management, whereas the project will be carried out in conjunction with catchment management works to decrease sediment loads entering the harbor. The work would begin in 2012/13 if consent is granted.

Box 9 Mahurangi Action Plan 2004-2009: benefit/cost information

The Mahurangi Action Plan was a pilot project, with an initial objective 'to halt, slow or reverse the adverse effects of sedimentation in the Mahurangi Harbour'. This table of costs and benefits is taken from EBG *et al.* (2012)

Action	Achievement	Cost $	Benefits– short term	Expected long term benefits
Fencing & riparian planting on private land	90 km of fencing on 22 rural properties 31 hectares planted (178,000 trees)	981,000	Stock excluded from waterbodies Reduced stream bank erosion Amenity values improved	Improved harbour health, due to reduction in sediment load
Farm plans	40 completed	219,000	Wider than above	As above
Volunteering	9500 hours	No direct charges	Awareness raising Enhanced commitment to MAP goals and implementation	Ethic of stewardship Various action on ground
Research	Numerous reports	Not known	Better understanding of catchment functioning and harbour ecosystem	Improved policy analysis i.e., more effective interventions
Monitoring	Routine SOE Community shellfish	Not known	As above	As above

Notes:
1. Total cost was $2m of which $1.2m was for the Landowner Assistance Fund.
2. The Landowner Assistance Fund provided a 75% subsidy to rural landholders for stream protection works on private land, mainly fencing and planting.
3. It is not clear how the balance (i.e., $800,000) was applied but it may have funded research
4. It seems that the reported costs did not include any allowance for Auckland Regional Council or Rodney District Council staff time or use of in-house resources
5. ARC funding of on-going research and routine monitoring does not appear to be included in reported costs.

Box 10 Elaborating the benefits of Social Capital

Encourages 'bonding' social capital between the community group – building trusting relationships
Encourages a sense of pride in place
Encourages 'linking' social capital, between land owner, community group and government agency
Gives a sense of power/control to communities
Social learning takes place – common understanding of problems and constraints for all stakeholders
Environmental stewardship from grassroots level
Makes use of existing networks and community groups, which is an efficient use of resources
Encourages personal responsibility, as opposed to dictated regulation

Box 11 Pahurehure Inlet Protection Society – Mangrove removal Papakura

The Pahurehure Inlet Protection Society is a community organisation that is active in mangrove management.

Two blocks of 13ha mangroves were removed in Pahurehure Inlet, in the Manukau Harbour (near Papakura). Estimated total costs for all works was $1.5 million. The estimated per hectare cost at Pahurehure was $50,000. As part of the agreed process of mangrove removal, a helicopter was used, at a cost of $15,000 per day. The mangroves were first mowed down and then bundled for aerial removal. It was estimated that the cost of removal could have been reduced to $1,500 per day, if machinery on a barge were used. There were restrictions on using any heavy machinery in the consent. Mangrove roots were not removed in the Pahurehure inlet, so the likely outcome is that sediment does not get washed out.
Dredging may be a longer-term objective to restore the estuary to the condition it was in 20 or 30 years ago.

The Pahurehure Inlet Protection Society relied on volunteers to remove the seedlings. The seedlings grew back year after year. Seedling removal was undertaken for three years. From now on (after removal in the 13ha blocks), it is estimated that seedling removal may be required twice a year. Ongoing costs of removing mangroves will accrue. Ideally, these clearances should be done annually, as over a year or two, there can be considerable regrowth. The current contract ran out in August 2012. The problem of pacific oyster invasion is also of concern to the Pahurehure Inlet Protection Society.

Step 5 – Documentation of Method

As much of the value in undertaking a cost benefit analysis is to do with understanding the policy problem and inherent trade-offs, the clarification of method and assumptions should be included. This would also include the timeframes under which the assumptions are relevant and the social discount rate used to express the costs and benefits in constant terms. This is especially the case for benefits, given that there are time lags to realise the outcomes of restoration projects. Any caveats associated with the data, whether it used the outcome of studies from another area (e.g. benefits transfer) should be included. Sensitivity analysis should also be undertaken, given uncertainties associated with project effects as identified in the scenarios. The costs and benefits should also be checked for double counting to ensure that the same benefit is not measured twice (e.g. use of hedonic pricing to measure increases in property values brought about by environmental restoration while also adding a willingness to pay measure for improved environment may count the same thing).

A discussion of the distribution of public and private benefits is important as it may influence the choice of action.[16] This is of particular relevance depending on how restoration projects are funded. Table 6 and 7 classify the costs and benefits into ‘public’ or ‘private’ – based on property rights regimes.

[16] A full discussion on the types of property ownership and use of resources in the context of riparian management in the Auckland area is given in Market Economics (2011).

Table 6 Summary of Public and Private Costs and Benefits of restoring Riparian Zones

	Private (including downstream farmers)	**Public**
Benefits	Improved stock health Improved water quality Soil improvement/nutrient retention Increased land values Production of marketable products (e.g. carbon credits, harvestable products) Marketing on environmental grounds	Amenity value of landscapes Ecosystem restoration and Ecological benefits Bequest of integral ecosystem to future generations
Costs	Loss of productive land Capital costs for alternative stock drinking stations	Indirect economic losses from change in production process
Distributed Costs (depending on which structure or programme is chosen in the scenarios)	Capital costs of fencing Labour costs for fencing/planting Cost of plants/shrubs/trees Ongoing maintenance costs	

Table 7 Summary of Public and Private Costs and Benefits of Harbour and Estuarine Health

	Private	**Public**
Benefits	Increased land values Marketing on environmental grounds Tourism opportunities	Amenity value of landscapes Ecosystem restoration and Ecological benefits Bequest of integral ecosystem to future generations Water quality Maori cultural heritage protected Social capital and partnership building Clean green image maintained
Costs	Dependent on how projects are paid for	Dependent on how projects are paid for

Of note is that the increased rates of sedimentation are a by-product from land-based activities. In effect the waterways have inadvertently been used as pipelines to the coastal areas for many generations. There are equity issues over paying for remediating the problem. The previous generations of foresters, landowners, farmers and city-builders contributed to the sedimentation problem, albeit unwittingly. As they are not around anymore, the burden of the costs fall onto the current taxpayers if remediation is pursued, and the benefits of healthy catchments accrue to future generations. This makes instituting the 'polluter pays principle' difficult, placing the onus on the beneficiary to pay, raising its own equity issues. Although not directly related to this report, a 'Catchment Care' principle with regard issues of who is paying for environmental restoration, or natural capital may be appropriate in this context (Box 12). Addressing the removal of mangroves in a singular location will benefit the local communities whose recreation and amenity values are being affected by their presence. These are quasi pubic goods.

Box 12 Principles of Equity: deciding who should pay for the environment

A number of principles exist to guide the normative decision within the governance of natural resources and the environment. These are beyond the realm of economic analysis, and are essentially political decisions. Economic analysis can inform the outcome of such decisions, but not determine which is the best principle to adopt.

The **Polluter Pays Principle** is based on the polluter taking financial responsibility for their actions. The polluter pays principle is similar to the user pays charging regime, based on the idea that consumers pay the full production costs of the goods they consume. According to this principle, the producer should pay for the full cost of their production, and internalise pollution costs. Ruffing (2010) notes that the polluter pays principle did not rule out all forms of subsidy, as the most efficient solution to some pollution problems can involve payments from a potential victim of pollution to the polluter. It also leaves room for pollution prevention and control measures such as direct subsidies, soft loans, guarantees and tax incentives, although circumstances under which such would be used, have been very limited. The polluter pays principle originated in the OECD.

The polluter pays principle is explicitly normative, stating an ethical position on who ought to bear the costs in a regulatory regime. If the principle accurately aligns with social preferences, using it as a policy will enhance economic efficiency as lobbying activity and transaction costs will be reduced. However there are problems of arbitration involved, establishing who the affected parties are (both now and in the future) and measuring how much they are affected.

The **Beneficiary Pays Principle** is based on the recipient of a good or service bearing the costs of its provision. If a person or group wants something, they should pay for that good or service. This is a rule applied to most private goods and services in the market. The beneficiary pays principle is useful for environmental goods or ecosystem service provision when the providers are poor and unable to pay (Hatfield-Dodds, 2006). This approach may be blocked by perceptions of poor public value for money. The approach may also risk the compensatory payments being used as a 'blocking tactic' rather than a negotiating basis e.g. holding the provision of healthy estuaries to ransom, until payments are made, and can also lead to dependency on such payments.

A complexity exists with environmental good provision as the beneficiaries may not be alive today – ecosystem services will benefit future generations. The beneficiary pays principle is similar to Payments for Environmental Services (PES) which are a policy response used as financial incentives for local actors to provide such services (Engel *et al*, 2008).

Another environmental economics principle is that of **Catchment Care** in the context of overcoming a policy impasse that may emerge due to advocates of the polluter pays and beneficiary pays principles, devised specifically in respect of water management. The concept was introduced by the Australian Wentworth Group[17] in 2002; formalised by Hatfield-Dodds (2006). The duality of both the polluter pays and beneficiary pays principles results in a 'winner takes all' situation in the short term. The Catchment Care principle states that 'individual resource managers have an obligation to avoid land or natural resource management practices that harm the long-term interests of resource users as a whole' (Wentworth Group, 2002). There is a requirement to maintain ecosystem integrity, interpreted as 'fully functional and productive landscapes, allowing a substantial degree of human modification within broad ecosystem parameters' (Hatfield-Dodds, 2006). The principle draws on aspects of established equity principles, but differs as it sets ecological benchmarks, and implies a minimum environmental standard that ecosystem integrity should be maintained (for future generations), rather than assuming that it is ethical for standards or outcomes to reflect current social preferences. The catchment care principle offers a principle-based approach that encourages cost sharing, overcoming the issue that benefits will be realised at a future date.

[17] The Wentworth Group of Concerned Scientists is an independent group comprising leading Australian scientists, economists and business people with conservation interests. Their first statement, *Blueprint for a Living Continent*, set out what it believed were the key changes that needed to be made to deliver a sustainable future, including emphasising the need to clarify water property rights and the obligations associated with those rights, and pay farmers for environmental services (clean water, fresh air, healthy soils) amongst others. http://www.wentworthgroup.org/

5.0 Discussion of the Approach

The cost benefit approach is premised on the implicit assumptions that welfarism provides the correct moral philosophy to guide public policy, that welfare is an individualistic and monistic concept, and that willingness to pay valuations correctly translate welfare impacts into monetary units (Sinden, Kysar and Driesen, 2009). Critiques of the basic premises of welfare economics are well documented in the economics literature (TEEB, 2010; Reiss, 2008; O'Connor, 2007), and are driving alterantive and emerging approaches to environment valuation and governance of conflicting trade-offs. The methodology detailed in Section 4 would measure the costs and benefits of changes brought about by intervention/expenditure on integrated catchment projects, of which mangrove management/removal is a component. The method uses scenarios, initially to establish the status quo, then to describe the likely changes that would take place. The benefits and costs are listed, based on reviews of similar studies undertaken. However much more detail and input is required to get an accurate account of the costs and benefits at each catchment level.

Cost estimates from various aspects of mangrove removal, riparian management and restoration projects undertaken to date were presented in boxes. This cost information can be obtained relatively easily for each catchment under consideration, as the services to undertake these are marketed. One of the major difficulties with this cost benefit analysis approach is valuation of environmental benefits. For environmental goods and ecosystem services, the consumer surplus is often infinite i.e. the services provided by the environment have infinite value as they cannot be replaced – if one relies on a marginal analysis. The arguments of Spash (2009) and Costanza *et al.* (1997) on critical natural capital are of importance. Market valuation techniques such as revealed preferences and willingness to pay generally understate the true non-market value of environmental goods and ecosystem services (Pearce and Moran, 1994; Balmford, *et al.,* 2002). The sheer cost of gathering revealed or stated preferences for the value of freshwater and estuarine restoration makes quantification of the benefits difficult. It is for this reason that Laycock *et al.*, (2011) propose the use of a cost-effectiveness analysis, prior to undertaking any non-market valuation. Cost effectiveness requires the calculation of costs (as per above methodology) but measures the costs against outcomes, rather than benefits (Box 13). These outcomes could be indicators such as sediment reduction, water quality, habitat preservation etc. For cost effectiveness a target or goal needs to be set in the form of these outcomes (particularly relating to biodiversity).

Box 13 Cost Effectiveness Analysis

Cost Effectiveness analysis looks at achieving a stated goal (outcome) by at least two different methods, and assessing the methods according to the lowest possible cost. Cost effectiveness analysis differs from cost benefit analysis as it avoids monetising the outcome or measure of effect. Cost effectiveness analysis is increasingly used in health economics and conservation programmes. With regard to application of cost effectiveness analysis of mangrove removal, the outcome does not have to be singularly the removal of mangroves from an area. The outcome could stipulate environment protection (e.g. sea grass maintenance), so the methods used are constrained by the intended outcome (e.g. herbicide use may be cheapest option, but not for consideration as a viable method, given the balanced goal of stated outcome).

Given that the cost benefit approach is based on scenarios, the status quo and a marginal analysis of changes brought about by intervention, there are a huge amount of assumptions and uncertainties. Cost benefit analysis is the 'rational' choice, thinking approach to decision making. As we increase our knowledge and scientific understanding about the confluence of land and sea, the complexities of the situation increase. Cost benefit encourages/leads to considerations of cause and effect. Starting from a community level, people want answers to questions about why their previously sandy beaches are being encroached, why channels are silting up etc. The scientific answer points to land use, land perturbations and disturbances over time. The 'rational' solution would be to institute the 'polluter pays' principle, but this is not possible since the sedimentation process has been gradual over time, caused by actions of past generations. The actions of present land owners affects current sediment loads, but the harbours and estuaries have accumulated this sediment over hundreds of years.

Rationalising a problem using a cost benefit framework is useful for a good understanding, but it does not necessarily lead to easy rational solutions to the environmental problems faced. Cost benefit analysis could show the likely effects of taking some action to remedy the problem, but it does not address the internalisation of pollution costs that have occurred in the past.

There is no easy formulaic means to address the issue of mangrove management through cost benefit analysis. The causes and effects of the changes in habitat of mangrove stretch over considerable timeframes – from the actions of past land owners to effects that current land use practice will be realised in the future. Natural and hydrological processes affect the dragging and settlement of sediment and ensuing colonisation of mangroves. Attempting to reduce all effects into monetary terms prior to making a decision will not ensure a better decision. It also assumes that if effects are in one common metric (dollars) that the trade-offs are substitutable. This may not be the case. Spash (2009) cautions against monetary reductionism for environmental decision making as it reduces significantly the level of pluralism in methods and understanding. This sentiment is very relevant in this instance, as the complexity of natural and human processes that affect estuarine health is immense.

Council can choose to fund projects to remove mangroves, as demand arises through Local Board processes. This action will incur the costs of physical removal, and will offer an immediate solution for the community requesting their removal. This solution may be temporary, as there is little published research on the mid to long term effects of mangrove removal. Ongoing maintenance of the site and future removal may be necessary. A cost schedule can be drawn up for such work, including consent, removal and ongoing costs into the future. The costs of such a project would receive the benefits of community satisfaction (for example, navigational access or recreational use). There is the question of opportunity cost of that money, of what that expenditure could have been spent on. Such removal needs to be seen within the larger context of the process of habitat evolution (e.g. sedimentation and mangrove growth) and an assessment of how possible it is to curtail that process through land management.

The Council can choose to address estuarine health and reduce the sediment that enters the coastal environment. This requires changes to land management practices, which can be introduced through regulation or through funded programmes. This would also require revisiting the ‘polluter pays’ principle, to ensure that all relevant costs are internalised by the market (e.g. land users not given the right to pollute). A further environmental consideration with regard to sediment relates to what happens to it after it leaves the harbours and estuaries, and whether it has negative effects on the receiving coastal environment, beyond the Council’s boundaries, and indeed the effects of terrigenous sediment in the ocean.

Cost benefit analysis is framed to answer questions of choosing between options, choosing one option over another. This is rather narrow in scope, given the multiple objectives of integrated catchment management/restoration and the acknowledged unknowns in the environment and ecosystem. A cost benefit analysis will not answer the question as to whether money spent on mangrove removal is good value as opposed to spending on integrated catchment management and controlling sediment. The benefits for both are not commensurate. The benefits of removing mangroves in a place where they are considered encroaching or where they are obstructing navigation channels will be realised immediately by those affected. The containment of sediment requires a much longer timeframe (decades) for the benefits to be realised. There is an issue of intergenerational equity involved with restoration projects.

A cost benefit approach may be appropriate to assess the most efficient means of ‘improving’ a harbour or estuary to a predetermined state, but this would require a significant assessment of one particular catchment using the approach, rather than a generic assessment of the variety of management options for the entire Auckland Council area.

With regards to expenditure on the environment, for restoration or enhancement, this can be seen as investment in natural capital. Capital, by definition, is used for productive purposes. Hence the link between the natural environment and the ecosystem services they ‘produce’. Arguments can be made for the need for ongoing maintaining natural capital. Expenditure decisions are taken on the maintenance of other types of capital – buildings, roads, parks and infrastructure without undertaking a full cost benefit analysis. Such decisions are usually made on the rationality of ‘continuity of service’ from those assets. This is part of asset maintenance.

6.0 Conclusion

This paper set out a methodology of how a cost benefit analysis would be undertaken with regard to mangrove management and integrated catchment of freshwater and harbours. Cost benefit consideration is a logical basis for making decisions, a rational approach to decision making regarding mangroves, recognising their role in the estuarine system. Cost benefit analysis is an economic tool that compares the net value of one course of action against another. It requires the articulation, measurement and monetisation of the costs and benefits brought about by the change in the course of action. The estuarine system is complex, and decisions regarding mangrove management and removal should be taken with an acknowledged uncertainty. That does not make the final decision any less valid, but it recognises that there is incomplete information of the human interaction with the natural system. Such decision making is acknowledged as being difficult, given that such complex systems pose 'wicked problems' to govern.

Economic instruments and tools are designed to correct market failure, to ensure that all consequential effects of an action are included in any rational analysis. Cost benefit analysis does this by translating values into a common monetary metric. A cost benefit framework is useful for its pluralist approach in identifying the wide range of costs and benefits. However by attempting to reduce these effects into monetary terms, much of the richness of the understanding of cause and effect is lost. This is especially the case if an analysis were taken at a regional level, as opposed to a harbour/location specific level. Cost benefit analysis shows net effects, and does not reveal information on who the main beneficiaries and losers are. For example, non removal of mangroves encroaching on the habitat of wading birds in an area may mean reduction or loss in the number of migratory birds. Putting a dollar value on this loss may be possible (depending on how it is valued), but when reducing all variables to monetary values and taking a decision on the relative weights of the loss or gain, the richness of detail of the valuation process gets obscured.

Augmenting a cost benefit analysis with consideration of equity can overcome the problem of loss of detail. This can be spatial equity (e.g. undertaking the analysis on a case specific basis, or a harbour by harbour basis), or distributional equity (e.g assessing who the winners and losers are), or intertemproral equity (e.g. benefits to future generations). A useful delineation should be made between classifying the costs and benefits into public or private, and assessing the main beneficiaries of a change in policy. Although an overall net benefit may result from a cost benefit analysis (which in strict 'pareto improvement' terms should mean that the change in question should be undertaken, as the winners can, in theory, compensate the losers), if these benefits accrue to one individual with no mandate or incentive to compensate the losers, an informed decision should be taken to assess whether the change that is being considered should go ahead. The valuation of public goods poses additional measurement problems, but should be included to inform the extent and levels of use of a mangrove area.

Given that beneficiaries of a policy may be residents of a particular harbour (e.g. improved recreational/navigational access if mangroves were removed, or provision of natural flood protection if mangroves were retained), it is useful not only to highlight but classify the beneficiaries, where possible. Equity issues will emerge, but should enable an assessment of how the economic instrument (e.g. policy change, or particular mangrove management programme) will affect private individuals and the community, now and in the future. For example, the provision of built infrastructure for flood protection may be incurred by local government rather than property owners and coastal communities, and the extent of the service provision for such public good services may influence a Council decision on how to manage natural resources. If the funciton of mangroves in flood control in the face of rising sea levels were agreed, the beneficiaries of that ecosystem service may extend beyond the immediate coastal community, to other ratepayers. The extent to which the public benefit may sway the decision taking, especially if the project or change of policy is being funded by the Council (public money). The intertemporal element may also influence the Council decision, as investment decisions are taken which would benefit future residents of Auckland at the expense of the current rate payers. These variables should be considered before taking the final decision.

Despite the shortcomings of cost benefit analysis as a decision support tool, decisions have to, and will be made, regarding the management of mangroves and catchments. Decision makers should not assume that all values are commensurable and that all resources are substitutable, as the monetisation of value sets brings one to accept.

The Council should set up a flexible process to evaluate mangrove management on a case by case, catchment by catchment basis, taking into account all other environmental management initiatives in that catchment. If mangrove removal is requested by the community, determining what the access is worth is an exercise that can be undertaken by calculating the costs of removal. The community or Council can assess the opportunity cost of that money, whether it is best spent on removal (and ongoing maintenance) or whether it would be better spent on other local initiatives. If mangrove removal is being considered, an overall public benefit should be demonstrated over individual or private benefit. In such a case, an assessment of the value sets within that estuary and catchment should be undertaken, along with the proposed method of mangrove removal and any considerations for local habitats or ecosystem.

7.0 References

Ackerman, F., Heinzerling, L and Massey, R (2004). *Applying cost-benefit to past decisions: was environmental protection ever a good idea?* Georgetown University Law Center, Public Law and Legal Theory Working Paper Series, Research Paper, 576161

Adler, M. and Posner, E. (2006). New foundations of cost-benefit analysis. Cambridge Ma., Harvard University Press.

Auckland Airport Ltd (2012). *Auckland Airport environmental management plan 2012 v0.4,* retrieved from the Auckland Airport Ltd website at: http://www.aucklandairport.co.nz/Social-Responsibility/Sustainability policy/~/media/Files/Community/Earthcheck/EMP2012.ashx (accessed on 13 February 2013)

Auckland Council (2011). Local Board plans. The 21 Local Board plans are available on the Auckland Council website at: http://www.aucklandcouncil.govt.nz/EN/ABOUTCOUNCIL/REPRESENTATIVESBODIES/LOCALBOARDS/Pages/Localboardplansandagreements.aspx (accessed on 13 February 2013)

Auckland Regional Council (2001a). *Auckland regional plan: sediment control.* November 2001

Auckland Regional Council (2001b). *Riparian zone management strategy for the Auckland region*. Technical publication 148

Auckland Regional Council (2004a). *Auckland Council regional coastal plan*. Available on the Auckland Council website at: http://www.aucklandcity.govt.nz/council/documents/regionalplans/coastal/aucklandregionalcoastalplanwholeplan.pdf (accessed on 13 February 2013)

Auckland Regional Council (2004b). *Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC*. Technical report 264, May 2004

Auckland Regional Council (2009). *A survey of the riparian characteristics of the Auckland region*. Technical report TR2009/002, August 2009

Auckland Regional Council (2010). *Ecosystem functioning, goods and services in the coastal environment.* Auckland Regional Council technical report, TR2010/033, July 2010

Auckland Regional Council and Papakura District Council (2006). *Pahurehure Inlet Management Plan. November 2006*. Auckland Regional Council and Papakura District Council with contribution from BECA Consultants

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K., and Turner K. (2002). Economic Reasons for Conserving Wild Nature. *Science* 297(5583), 950–953.

Batstone, C (2009). *Methods for evaluating coastal receiving environments and the effects of stormwater: phase II report*. Prepared by Cawthron Institute for Auckland Regional Council

Batstone, C and Sinner, J (2010). *Techniques for evaluating community preferences for managing coastal ecosystems. Auckland region stormwater case study, discrete choice model estimation.* Prepared by Cawthron Institute for Auckland Regional Council. Auckland Regional Council technical report, TR2010/012

Bebbington, J., Brown, J and Frame, B (2007). Accounting technologies and sustainability assessment models. *Ecological Economics,* 61, 224-236

Brooks, J., Davis, A., Baird, K., Bellingham, M (Part 1) and Zimmerman, R (Part 2). (2011). *Issues and options for the conservation and recovery of the critically endangered New Zealand fairy tern.* Report prepared for Forest and Bird Protection Society of New Zealand, December 2011

Chichilnisky, G (1997). The costs and benefits of benefit-cost analysis. *Policy Forum*, 202-205

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K. Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. and van den Belt, M (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387, 253-260

Currie, B., Milton, S. and Steenkamp, J (2009). Cost-benefit analysis of alien vegetation clearing for water yield and tourism in a mountain catchment in the Western Cape of South Africa. *Ecological Economics*, 68(10), 2574-2579

Davis, D. and Gartside, D (2001). *Challenges for economic policy in sustainable management of marine natural resources. Ecological Economics*, 36, 223-236

EBG, Planning Consultants Ltd and D&B Kettle Consulting Ltd (2012). *Evaluation of three catchment initiatives.* Report prepared for Auckland Council

Engel, S, Pagiola, S and Wunder, S (2008). Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics,* 65(4), 663-674

Environment Waikato (2009). *Assessment of physical changes after mangrove removal: Whangamata Harbour 2008*. Environment Waikato technical report 2009/13

Favereau, O. and Lazega, E. (eds.) (2003). *Conventions and structures in economic organisations. Markets networks and hierarchies.* Cheltenham: Edward Elgar

Frank, R. (1998) Microeconomics and Behavior. New York: McGraw-Hill

Freeman, A. M. (2003). *The measurement of environmental and resource values – theory and method.* Washington, Resources for the Future, second edition

Friedman M (1953). *Essays in Positive Economics*. Chicago. University of Chicago Press

Gao, J., Chen, H., Zhang, Y., and Zha, Y (2004). Knowledge-based approaches to accurate mapping of mangroves from satellite data. *Photogrammetric Engineering and Remote Sensing*, November 2004, 1241-1248

Gasparatos, A., El-Haram, M. and Horner, M (2009). The argument against a reductionist approach for measuring sustainable development performance and the need for methodological pluralism. *Accounting Forum*, 33(3), 245-256

Gibbs, M. and Hewitt, J (2004). *Effects of sedimentation on macrofaunal communities: a synthesis of research studies for ARC*. Report prepared for the Auckland Regional Council by NIWA, ARC Technical Publication, 264

Gilbert, A. and Janssen, R (1998). Use of environmental functions to communicate the values of a mangrove ecosystem under different management regimes. *Ecological Economics*, 25, 323-346

Hahn, R. and Dudley, P (2007). How well does the government do cost-benefit analysis? *Review of Environmental Economics and Policy,* 1(2), 192-211

Hart, G (2011). *Vulnerability and adaptation to sea-level rise in Auckland, New Zealand*. Victoria University of Wellington, New Zealand Climate Change Research Institute report 08, October 2011

Harty, C (2009). Mangrove planning and management in New Zealand and South East Australia – a reflection on approaches. *Ocean and Coastal Management,* 52, 278-286

Hatfield-Dodds, S (2006). The catchment care principle: A new equity principle for environmental policy, with advantages for efficiency and adaptive governance. *Ecological Economics,* 56(3), 373-385

Hauraki Gulf Forum (2011). *State of our Gulf. Tikapa Moana – Hauraki Gulf State of the Environment Report 2011*.
http://www.aucklandcouncil.govt.nz/EN/AboutCouncil/representativesbodies/haurakigulfforum/Documents/hgfstateoftheenvreport2011.pdf

Hayward, B and Morley, M (2005). *Intertidal life of the Tamaki Estuary and its entrance, Auckland.* Report prepared for the Auckland Regional Council, technical publication, 373

Hicks, J (1943). The four consumer's surpluses. *The Review of Economic Studies*, 11(1) Winter, 1943, 31-41

Horton, R., Herweijer, C., Rosenzweig, C., Liu, J., Gornitz, V. and Ruane, A (2008). Sea level rise projections for current generation CGCMs based on the semi-empirical method. *Geophysical Research Letters*, 35, L02715

Jones, H (2008). *Coastal sedimentation: what we know and the information gaps*. Environment Waikato technical report 2008/12

Kahneman, D (2011). *Thinking, fast and slow*. Farrar, Straus and Girous publication

Kahneman, D. and Tversky A (1979). Prospect theory: an analysis of decision under risk. *Econometrica,* 47(2), 263-292

Kerr, G. and Sharp, B (2003). *Lost Streams: Determining compensation requirements using choice modeling*. Report prepared for the Auckland Regional Council, ARC technical publication 212

Kysar, D.A. (2010). *Regulating from Nowhere: Environmental Law and the Search for Objectivity.* New Haven: Yale University Press.

Laswell, H (1951). The policy orientation. In: D. Lerner and H. Lasswell (eds). *The policy sciences*. Stanford CA: Stanford University Press

Laycock, H., Moran, D., Smart, J., Raffaelli, D. and White, P. (2011). Evaluating the effectiveness and efficiency of biodiversity conservation spending. *Ecological Economics,* 70(10), 1789-1796

Lewis, D (1969). *Convention. A philosophical study*. Oxford: Basil Blackwell

Market Economics (2011). *Assessing riparian management initiatives in the Auckland region. Final report to the Auckland Council*, August 2011

Ministry for the Environment (2003). *Drafting issues, objectives, policies and methods in regional policy statements and district plans* http://www.mfe.govt.nz/publications/rma/drafting-issues-jul03/html/index.html (accessed on 13 February 2013)

Mintzberg, H. and Westley, F (2001). Decision Making: It's not what you think. *MIT Sloan Management Review*, Spring 2001, 89-93

Miskelly, C.M.; Dowding, J.E.; Elliott, G.P.; Hitchmough, R.A.; Powlesland, R.G.; Robertson, H.A.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A (2008). Conservation status of New Zealand birds. *Notornis*, 55, 117-135

Morrisey, D., Beard, C., Morrison, M., Craggs, R. and Lowe, M (2007). *The New Zealand mangrove: review of the current state of knowledge*, Auckland Regional Council technical publication 325

NIWA (2010). Waikato River Independent Scoping Study. Hamilton, National Institute of Water and Atmospheric Research Ltd. http://www.mfe.govt.nz/publications/treaty/waikato-river-scoping-study/wriss-final-report.pdf (accessed on 13 February 2013)

O'Connor, M (2002). Reframing environmental valuation: reasoning about resource use and the re-distribution of sustainability. In: Hussain Abaza and Andrea Baranzini (eds.) *Implementing sustainable development*. Cheltenham, UK and Northampton, MA, USA: Edward Elgar

O'Connor, M (2007). P*aradigms for sustainability assessment: inventory of costs and benefits versus representative diversity of indicators*. Background paper in support of the SEEA 2010 reform
OECD (2008). *People and biodiversity policies*. Paris: OECD Publications

Ormerod, P (1999). *Butterfly economics: a new general theory of social and economic behavior*. New York: Pantheon

Patterson, M and Cole, A (1999). *Assessing the value of New Zealand's biodiversity*. Palmerston North, Massey University, Occasional paper 1

Pearce, D 1998. Cost-benefit analysis and environmental policy. *Oxford Review of Economic Policy*, (14)4

Pearce, D and Moran (1994). *The economic value of biodiversity*. London: Earthscan

Peart, R (2007). *Beyond the tide integrating the management of New Zealand's coasts.* New Zealand: Environmental Defence Society

Reiss, J (2008). E*rror in economics. Towards a more evidence-based methodology*. London: Routledge.

Ruffing, K (2010). The role of the Organisation for Economic Cooperation and Development in Environmental policy making. *Review of Environmental Economics and Policy*, 4(2), 199–220

Saaty, T (2008). Decision making with the analytical hierarchy process. *International Journal of Services Sciences,* 1(1), 83-98

Saaty, T (1980). T*he analytical hierarchy process*, John Wiley, New York.
Schwarz, A. (2003). Spreading mangroves: a New Zealand phenomenon or a global trend? *Water & Atmosphere*, 11(1), 8-10

Simenstad, C., Reed, D. and Ford, M (2006). When is restoration not? Incorporating landscape-scale processes to restore self-sustaining ecosystems in coastal wetland restoration. *Ecological Engineering*, 26, 27-39

Simon, H A (1955). A behavioural model of rational choice. *Quarterly Journal of Economics*, 69, 99-118

Simon, H A (1959). Theories of decision-making in economics and behavioural science. *The American Economic Review*, 49(3), 253-283

Sinden, A., Kysar, D. and Driesen, D (2009). Cost-benefit analysis: New foundations on shifting sand. *Regulation and Governance*, 3, 48-71

Spash, C. (2009). The new environmental pragmatists, pluralism and sustainability. *Environmental Values,* 18(3), 253-256

Stokes, D J (2010). *The physical and ecological impacts of mangrove expansion and mangrove removal: Tauranga Harbour, New Zealand*. Thesis, PhD. University of Waikato

Swales, A., Bell, R., Gorman, R., Oldman, J., Altenberger, A., Hart, C., Claydon, L., Wadhwa, S., Ovenden, R (2008). *Potential future changes in mangrove-habitat in Auckland's east-coast estuaries*. Auckland Regional Council technical report TR2009/079

TEEB (2010). *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB.* The Economics of Ecosystems and Biodiversity. http://www.teebweb.org (accessed on 13 February 2013)

Tonkin & Taylor Ltd (2007). *Waiuku coastal compartment management plan volume I.* Report prepared for the Auckland Regional Council and Franklin District Council

Townsend, M. and Thrush, S (2010). *Ecosystem functioning, goods and services in the coastal environment.* Report prepared by the National Institute of Water and Atmospheric Research for the Auckland Regional Council. Auckland Regional Council technical report TR2010/033

Treasury New Zealand (2005). *Cost benefit analysis primer*. Version 1.12. Wellington, December 2005.

Turner, R., Paavola, J., Cooper, P., Farber, S., Jessamy, V. and Georgiou, S. (2003). Valuing nature: lessons learned and future research directions. Ecological Economics, 46, 493-510

Veitch, C R and Habraken, A M (1999). Waders of the Manukau Harbour and Firth of Thames. *Notornis*, 46, 45-70

Wilson, R (2011). *Cost benefit approaches: case studies in New Zealand*. Unpublished internal briefing for the Research, Investigations and Monitoring Unit of Auckland Council, May 2011

Weber, M (1905). Objective possibility and adequate causation in historical explanation. Published in The *methodology of the social sciences*, 1949 E Shils and H Finch (eds.)

Weick, K (1995). *Sense making in organizations*. Sage Publication

Wentworth Group (2002). B*lueprint for a living continent: a way forward from the Wentworth group of concerned scientists*. Report to Premier Carr. WWF, Sydney. Available from www.wwf.org.au (accessed on 13 February 2013)

Young, L (2002). Determining the discount rate for government projects. New Zealand Treasury Working Paper 02/12, September 2002