Solution-oriented Systems Thinking Archetypes; examples from the Manawatu River, New Zealand

Van den Belt, M., Forgie, V., M. Scott, A. Frampton and A. Obeidat

Abstract

Most representations of Systems Thinking Archetypes explore problematic systemic causalities. Policy or management guidance from Systems Thinking Archetypes is generally directed toward understanding new and delayed feedback loops, exposing critical connections and revealing invisible underlying structure. This paper explores Systems Thinking Archetypes from a solution-oriented perspective. Instead of identifying problems the focus shifts to solutions generation to achieve a higher level at which to intervene in a system (Meadows, 1999). Recognizing that problems and solutions are interconnected, we argue that language may be important, especially when the goal is to move beyond incremental improvements towards generating a level playing field for more courageous, vision inspired changes (Senge, 1990). For the Manawatu River Catchment, examples of eight archetypical behaviors and a solution-oriented adaptation of the archetype decision-tree (as proposed by Goodman and Kliener (1994)) are presented. The desired outcome is to support on-going multi-stakeholder dialogues with a positive frame and move beyond incremental problem solving catchment management to a higher level of solutions generation.

1. Introduction

Systems thinking and its conceptual tools, such as causal loop diagrams (CLDs) provide a means for decision-support. The aim of these conceptual tools is to deepen the understanding of interdependencies, difficulties of implementation, impacts of assumptions, and to provide further insights into organisational behaviour (Bardoel & Haslett, 2004). While the generally accepted 'archetypes' are primarily geared toward a business context to overcome managerial challenges, we propose solution-oriented archetypes for a multi-stakeholder context for the management of a watershed.

Systems archetypes are generic CLD structures which show intended actions, unintended consequences and delays in reaction time (Wolstenholme, 2003). They reveal reoccurring often counter-intuitive patterns of behaviour (Senge, 1990, 1994; Wolstenholme, 2003). They can be used as a diagnostic tool to provide insights into the underlying structure which determines behaviour or to test prospective policies and new configurations (Braun, 2002) and intervene at a higher level of leverage in a system (Meadows, 1999). Currently, systems thinking archetypes are used by some business administrators and practitioners to explore system causalities in a problematic context (Goodman and Kliener,1994). Our paper explores the benefits of, and the rationale for, applying the same systems thinking archetype structure in a solution-oriented context, but re-worded and shifting from the management of one organization to that of a watershed. Examples for how this could work come from the Manawatū River Catchment (MRC). The solution-oriented archetypes are then combined into an archetype decision tree (Goodman and Kliener, 1994) to provide a positive narrative for the MRC. Senge et al., (1994) describe an archetype decision tree as a diagnostic tool that sets out how archetypes are strategically related to each other.

Many studies that focus on solutions generation highlight the benefits of creative envisioning as a means for moving from problems to solutions. Research shows that identifying appropriate leverage points is an important means of influencing decision-making at both the individual and organisational level (Meadows, 1999). It is at this level we argue that a solution-oriented archetype decision tree has the potential to illustrate the combined benefits of multi-stakeholder solutions for environmental problems. The generation of a shared vision between individuals creates a shared mental model and cognitive frame of reference, thus increasing a social unit's ability to absorb new external information, as well as strengthen the ties within the group.

1.2 Rationale

1.2.1 *Systems Archetypes, Mental Models and the 'Fifth Discipline'*

When Senge (1990) identified systems archetypes, he identified patterns of causal loops that generate the same types of behaviour, which consistently appear throughout various types of systems (Bardoel & Haslett, 2004). These archetypes serve as a language for communicating complexities and interdependencies and to clarify and summarise complex issues, as well as clearly identify the key elements involved in a situation (Braun, 2002; Wolstenholme, 2003; Senge, 1990) further stated that systems archetypes are mental models, and defines these as "deeply ingrained assumptions, generalisations, or even pictures of images that influence how we understand the world and how we take action" (p.8). A mental model will affect how administrators see the world and, therefore, how they will act within any environment. Scholars have also shown that individuals cannot recognise, understand, and exchange unique knowledge without some shared cognitive frame of reference such as a mental model. Arguments commonly emphasise that shared (or common) knowledge is a key dimension of relationships to facilitate learning (Kang, Morris & Snell, 2007) and the findings of such studies indicate that the process of envisioning by stakeholders, through the use of a solution-oriented archetype decision tree, could allow for a shared mental model and cognitive frame of reference, thus allowing for exchanges of unique knowledge within a group. Senge (1990) outlined five disciplines that lead to a capacity of generativity –a quality important for innovation, as it is the ability to adapt and to create alternative futures – rather than just adaptive capacity (Watkins & Marsick, 1992). These five disciplines include: developing personal mastery with an emphasis on clarifying personal vision; having mental models which distinguish data from assumptions and which test assumptions; building shared visions; understanding the power of team learning; and, the fifth discipline, which is systems thinking. The utilization of these disciplines allows people to connect to the whole picture, rather than to analyse and dissect information and the world into fragmented and distanced pieces (Watkins & Marsick, 1992). These disciplines are also grounded in the philosophy of 'creative tension', which evolves from envisioning, and is described as the ability to clearly see where one wants to be, whilst telling the truth about the current reality. The creative tension results from the distance between the truth of the present reality and the vision with which one is aligned with (Mento, Jones & Dirndorfer, 2002).

1.2.2 The Effects of Intrinsic and Extrinsic Motivations in Decision-Making

Studies conducted on human creativity also support the potential of a solution-oriented archetype decision tree, as they have shown that human creativity is a good predictor of invention, and that intrinsic motivation is conducive to this creative performance (Amabile, 1979, 1982b, 1983; Amabile, Hennessey & Grossman, 1986; Reeve & Deci, 1996; as cited in Selart *et al*, 2008). An intrinsic motivation denotes the personal aspects of motivation that originate within an individual and which are subject to the individual's volitional control to some degree. The other known form of motivation is that of extrinsic motivation, and this denotes the external aspects of motivation which originate outside of the individual and which are not subject to the individual's volitional control (Brewer, Dunn, Olszewski, 1988). A solution-oriented archetype decision tree would focus on the internal factors influencing decision-making, as the motivation to achieve the desired outcome would be borne from alignment with an internal and shared goal, or vision. It has also been shown that strong intrinsic motivation is important for the development of new ideas, persistence of effort which enables step by step elaboration of the implications of a new idea, correction of possible errors, willingness to take risks, testing the validity of hypotheses and foreseeing the practical consequences and the ethical implications of novelty (Krippendorff, 2004). Utilising intrinsic motivation, through the use of a solution-oriented archetype decision tree could, therefore, allow for greater invention and innovation within decision-makers.

1.2.3 It's All About The Narrative: The Benefits of a Solution-Oriented Archetype Decision Tree

A solution-oriented archetype decision tree also offers a group a tool that can be used to create a narrative about the situation in question. It has been shown that stories appear to enable "knowledge-sharing experiences, through narratives that build trust, cultivate norms, transfer tacit knowledge, facilitate unlearning, and generate emotional connections" (Sole & Wilson, 2002, pp. 3-4; as cited in Dalkir & Wiseman, 2004). This concept has been further extended upon with the argument that while all stories are narratives, not all narratives are good knowledge-sharing narratives (Dalkir & Wiseman, 2004). The use of a solutions-oriented archetype decision tree could give participants the opportunity to collectively create a narrative that has positive outcomes, whilst also facilitating the transfer of tacit knowledge and the generation of trust between those involved. The process of creating and determining the narrative for a situation then has the ability to change existing problem-oriented paradigms to ones that are solution-oriented because this process would involve the creation of new paradigms through volition, rather than conforming to pre-existing paradigms associated with the narratives of problem solving.

1.2.4 How to Intervene in a System

The solutions oriented archetypes and decision tree are intended to provide a way of intervening in the system at a higher level by integrating information and challenging the business-as-usual approach to change. Contemporary institutional research (Vasi, 2007) shows that the uptake of environmental organisational practices is influenced by the rules and structures that are built into the wider environment. Other studies (Campbell & Lindberg, 1990; Dobbin & Sutton, 1998; as cited in Vasi, 2007) conceptualise that the State is the most important level of nested organisational fields, as it plays the role of institutional actor, and defines and encourages the perception of practices and “natural order of things.”

Kuhn (1970) studied the way in which scientific knowledge is acquired and the process by which an older theory is replaced with a new one. At the core of his analyses, was the idea of paradigms, initially defined as “universally recognised scientific achievements that for a time provide model problems and solutions to a community of practitioners” (Kuhn, 1970, p. viii). Given the current state of environmental and ecological health, the need for effective action and direction from organisations and decision makers from all hierarchal levels is necessary. One such way to achieve this is by moving to positively framed goals rather than reacting to negatively framed problems.

Donella Meadow’s “leverage points” publication sets out the different points within a complex system, where a small change in one part can produce substantive changes throughout. Leverage points are the ‘power points’ in a system but seldom intuitive (Meadows, 1999). As a result, there is a tendency for people and institutions to put effort into things that have least impact as they only make marginal adjustments rather than questioning the rational for the system as it currently exists. The solutions oriented archetypes and decision tree are intended to provide a way of relooking at the system and moving up the hierarchy towards more effective leverage points such as driving positive feedback loops. This is at least at level 7 for Meadows (1999, 3) who formulated the following leverage points listed in increasing order of effectiveness:

12. Constants, parameters, numbers (such as subsidies, taxes, standards)
11. The sizes of buffers and other stabilizing stocks, relative to their flows
10. The structure of material stocks and flows (such as transport networks, population age structures)
9. The lengths of delays, relative to the rate of system change
8. The strength of negative feedback loops, relative to impacts they are trying to correct against
7. The gain around driving positive feedback loops
6. The structure of information flows (who does and does not have access to what kind of information)
5. The rules of the system (such as incentives, punishments, constraints)
4. The power to add, change, evolve, or self-organise system structure
3. The goals of the system
2. The mindset or paradigm out of which the system – its goals, structure, rules, delays, parameters – arises
1. The power to transcend paradigms

1.2.5 The Manawatu River Catchment

The Manawatu River Catchment drains a watershed of 5,944km^2 (594,400ha) in the lower North Island of New Zealand (Figure 1). The main land use activity in the MRC is agriculture. Over the last 10 years sheep and beef farming has declined and dairying increased. The catchment also has a number of urban settlements located alongside the river, the largest of which is the city of Palmerston North (population 80,000). Discharge from the city's wastewater treatment plant, as well as many other small urban settlements goes into the river or its tributaries.

Since a major national newspaper published a negative story (Morgan & Burns, 2009) about the level of pollution in the Manawatu River, there has been a surge public interest in cleaning up the region's waterways. Several key contributors to the water quality problem have been clearly identified in the catchment area.

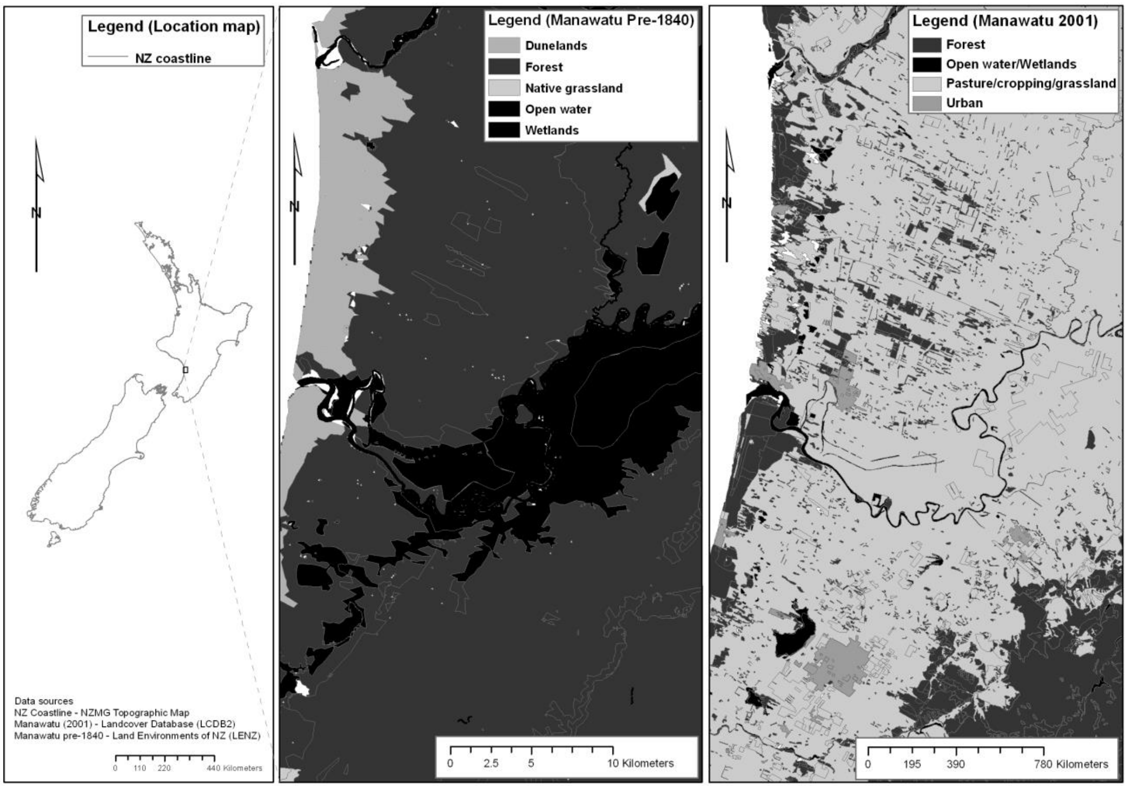

Figure 1 The Manawatu River Catchment

Arguably one of the most important issue to the MRC is nutrient leaching, which comes from two main sources. The first is nitrogen run-off from farms in the catchment. This problem is particularly acute on farms where cows are allowed to walk in waterways to drink, because their effluent is deposited directly into the water and washes downstream. The second source of nutrients is from inadequately treated sewage from town and city treatment facilities discharging to waterways. Both of these sources, farm run-off (non-point sources) and town wastewater treatment (point sources), are adding excessive amounts of nutrients, particularly nitrogen and phosphorus, into the Manawatu. In a process referred to as eutrophication, these cause algal-blooms that, especially during the night-time respiration cycle, can starve the river of oxygen, killing some river species and driving others elsewhere.

Waterborne pathogens from both farms and towns are also an issue. Dangerous levels of e-coli and faecal coliforms have led the councils to issue hazard notices warning against swimming and fishing on the river. The Council periodically issues warnings of toxic algal blooms related to eutrophication.

Another issue that affects water quality is erosion in steep areas of the catchment. Removal of forest cover has resulted in erosion being a problem in the Manawatu watershed. Erosion is accelerated by the geology and topography of the region and the fact that 62% of the hill country area is used for pastoral farming. According to the Ministry of Agriculture and Forestry (2010), 274,000ha of the total 594,400ha are prone to high rates of erosion and another 76,000 ha (12% of the watershed) have the potential for severe erosion. Erosion not only removes fertile soil from slopes but also damages aquatic ecology: it increases suspended matter in the water; it raises the level of the riverbed, and; the sediment washes into the space in the rocks, depriving invertebrates and river-fish of a habitat. The Manawatu river currently washes downstream an average of 3.8 million tonnes of sediment per year (Schierlitz, Dymond & Shepherd, 2006).

There has been a great deal of public interest and political will to improve river water quality and habitat. People involved with policy and advocacy around water quality are aware of the issues on the river, and some positive steps are being taken. A Mediated Modeling process: i.e. model building *with* rather than *for* stakeholders (van den Belt, 2004) was pursued during 3 workshop days (van den Belt et al, 2013a). However, the political nature and speed of the stakeholder interactive process prompted graduate students of the 2012 Applied Ecological Economics course (Massey University 132.705) based on interactions with the faculty and stakeholders, to take a step back from System Dynamics and instead develop CLDs for the MRC. The following section explores how the new archetypes can help identify, and demonstrate to stakeholders, the dynamics of positive CLD based stories for the catchment.

2. Method

The envisioning process of solutions-oriented systems requires the reworking of eight of Senge's archetypes. Wolstenholme (2003) restructured archetypes that have problem behaviour into new archetypes that have solutions behaviour by incorporating a solution link. In this paper we rename the archetypes, identify how the causal loop diagrams could be used in a solution-oriented manner, by looking at the dynamic Senge's original archetypes were expressing. We then used the same dynamics to harness positive, solution-oriented outcomes.

In most cases, the original dynamic was avoiding negative outcomes; either unintentional effects of a decision (Fixes that Fail, Escalation, Success to the Successful and Tragedy of the Commons) or a failure to understand the changes in behaviour that happen over time (Drifting Goals, Shifting the Burden, Growth & Underinvestment, Limits to Success and Addiction). To use 'Success to the Successful' as an example, the dynamics in this archetype express a situation where energy or attention is directed at one of two options and the momentum of that energy is such that the favoured option becomes dominant to the detriment of the alternative, which may have equal potential.

We then looked at how those dynamics could help us in the field that we were studying (water quality in the Manawatu River Catchment area) and affect positive change in the area. As an example the dynamics of ‘Success to the Successful’ were applied to a solution to use price signals to phase out a source of river contamination.

A similar process was followed with other archetypes. In some cases, the new archetype was quite similar to the original (Long-term Investment in Natural Capital, for example, is very similar to the Growth and Underinvestment archetype that it is based on), while others were quite different. In one case, in order to reflect the positive effect of collaboration, the dynamics themselves needed to be reassessed. This is explained further in the discussion.

3. Results

This section describes the solution-oriented archetypes, developed by graduated students and faculty. These are transformations of the original problem-oriented archetypes. For each archetype the original Senge (1990) version is identified in brackets in the heading. Following a description of the solution-oriented archetype, an example is given to show its value for providing solutions to water quality problems in the MRC.

1.1 Internalising an Externality (Success to the Successful)

This archetype describes the dynamics involved in including the cost of a negative externality in the product, thereby “internalizing” it. A negative externality is an adverse effect not borne by the producer or user of a product or service. An example is waterway pollution, which has a negative effect on the wider environment and community.

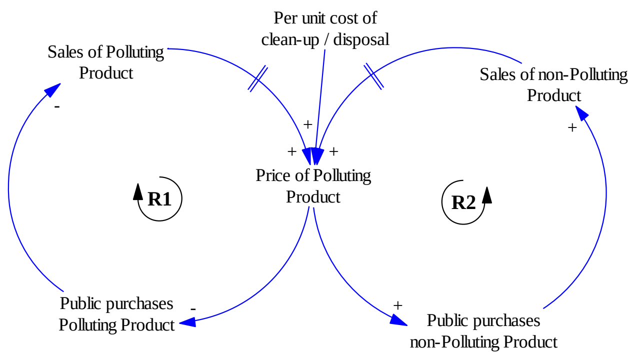

Figure 2 Internalising and Externality

With the ‘Internalising an Externality’ archetype a value is assigned to the clean-up cost of a polluting product, and that cost added to the product at the point of sale. The money generated can be used to pay for the clean-up and in addition the higher price will encourage consumers to buy less-polluting alternatives. As consumers move away from the polluting product, it may also become more expensive due to the loss of economies of scale. This also makes the non-polluting alternative more attractive and if sales increase sufficiently economies of scale will allow prices to be maintained at a price less than the polluting product. Supermarkets might also decide to stock a range of the alternatives and phase out the polluting product. Figure 2 shows the dynamics of the new archetype.

In the Manawatu Catchment area, this model could be applied to phosphate detergents. As part of its consent to discharge wastewater into the river, the Palmerston North City Council must remove a large proportion of the phosphorus in wastewater, much of which comes from household detergents. To do this the council spends NZ$3000/day on aluminium sulphate treatment (Horsely, 2012). It is, therefore, possible to assign a value to the amount of aluminium sulphate required to neutralise the phosphates in detergents and to add that cost to the total cost of the product at point of sale.

1.2 Incentivising Innovation (Shifting the Burden)

Senge's archetype "Shifting the Burden" is already somewhat solution-oriented, though it's other title, "Addiction", perhaps less so. Here we have renamed it "Incentivising Innovation". This CLD describes the effect of shifting the burden of clean-up from an "externality", borne by the community, to the source. The source could be an industry that produces a polluting product or one that contributes to pollution as a by-product of its operations.

In this scenario, the manufacturer is asked to pay the total cost of pollution. This additional cost encourages the manufacturer to become more innovative and either clean up waste on site, or invest in less polluting alternatives. If this is not done the polluter must compensate with pay for the degraded ecosystem. In the archetype (Figure 3) the incentive of payments for ecosystem services eventually leads to the producer minimising their pollution, and in the short-term the community has an income to carry- out waterways clean-up.

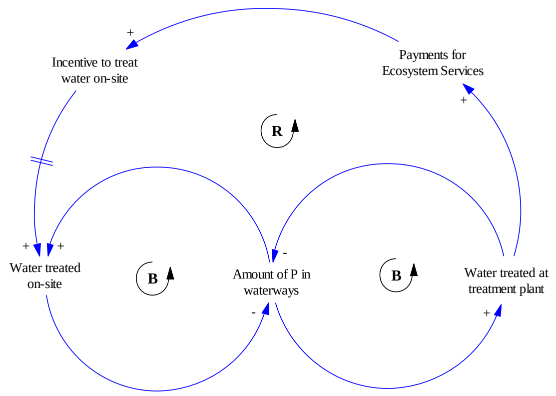

Figure 3 Incentivising Innovation

In the MRC, this archetype could apply to industries in the catchment area that contribute substantial amounts of phosphorus to the city's wastewater treatment plant. In 2011, the city introduced a monitoring system and a charge for industries that contribute higher than domestic levels of phosphorus (Rankin, 2011). Over time, if the charges are substantial, we expect to see industries looking to change their processes or invest in on-site phosphorus mitigation as a result of the burden of waste treatment being transferred back to them. If this is done using wetlands which have the potential to absorb excessive nutrients there are additional benefits such as habitat for local wildlife.

1.3 Cleanup Competition (Escalation)

Another way that Senge's archetypes can portray a solution for pollution control is based on the dynamics of the "Escalation" archetype. The original archetype shows how two balancing loops can "feed" off each other to produce a counter-productive escalation (such as an arms race). However, two balancing loops can also "feed" off each other to produce a positive outcome, such as lower levels of pollution.

This dynamic can be transformed into a positive, solution-based archetype by looking at how effectively-directed public attention can lower pollution levels in an area. Figure 4 below looks at two or more towns (or companies) that are contributing to pollution in a given catchment or region. When public attention is directed to the issue, there is pressure on the biggest polluter to eliminate or mitigate their contribution. As their proportion to the total amount goes down, another town or company becomes the biggest polluter and they in turn feel public pressure to reduce their contribution to total pollution. If sustained, this "competition" between towns or businesses has the effect of considerably reducing pollution.

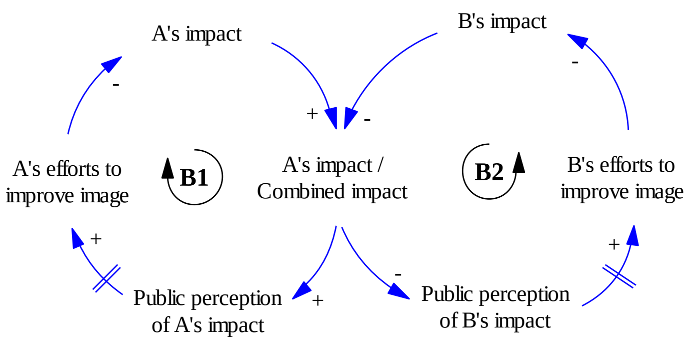

Figure 4 Cleanup Competition

This clean-up dynamic is already evident in the MRC. Considerable public attention has been focussed on the Manawatu River water quality since the 2009 report. Public scrutiny directed at key polluters in the catchment has seen gradual improvements in water quality as each town or industry makes upgrades to their waste management facilities or changes their practices.

1.4 Benefits of Collaboration / Many Hands Make Light Work (Tragedy of the Commons)

Senge's Tragedy of the Commons archetype describes the dynamics of individual actions for private benefit resulting in an undesired collective outcome, such as the loss of a common asset. This is shown as two reinforcing loops (representing individual effort and gain) on the outside, and two balancing loops (representing collective effort and gain) on the inside. The archetype effectively describes many of today's social issues, from overfishing to global warming. However, an adjustment to this model can show another, equally useful scenario, wherein the benefits of working collectively are greater than the sum of individual private benefits.

In the adapted archetype the balancing loops are on the outside, describing individual effort and gain, and the inside loops are reinforcing. With the Benefits of Collaboration archetype

(Figure 5) collective investment provide greater returns than individual investment due to scale.

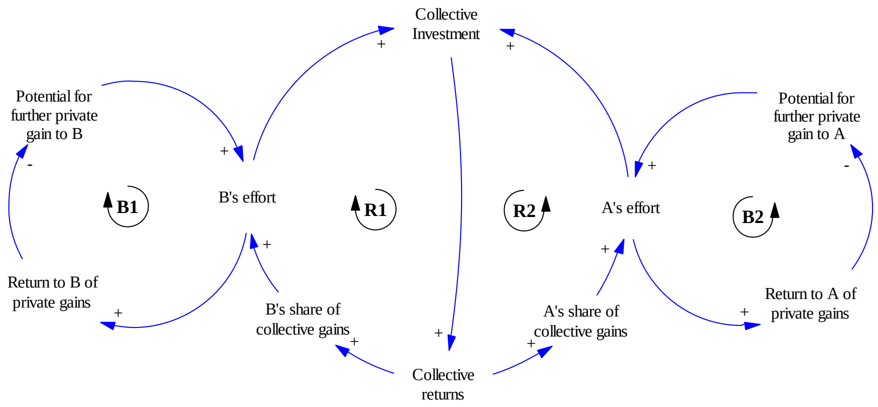

Figure 5 Benefits of Collaboration

One solution for improving water quality in the MRC involves farmers fencing off streams and planting trees to prevent fertiliser and effluent washing into the waterways. If one farmer in an area does this, it has some effect on water quality. If all farmers in a given catchment area fence off and plant trees, it has a very dramatic impact on water quality in that catchment area. As well as the improvement in water quality there is increased biodiversity and wildlife. Streams become recreation areas for fishing and swimming. Areas with good water quality and forested areas usually have higher real estate values. There are also potential business opportunities for farmers to jointly provide walking tracks and lodging, as has been done in other parts of New Zealand, for example the Banks Peninsula Track (Hargreaves, 2002). Many farms have small blocks of native forests, some of which cross boundaries between farms. Those forests may qualify for carbon credits collectively, but may be too small to qualify as individual private forests.

1.5 Finding the Appropriate Scale (Drifting goals)

Senge's archetype 'Drifting Goals' demonstrates the unwanted tendency of organisations to lower their goals as they become more difficult to meet. A similar diagram can be used to express the dynamics of balancing natural capital and built capital. Natural capital, which provides habitat, water regulation, water purification and many other services, supports economic activity. Built capital is necessary for productive enterprise. Both require a land-base in order to function.

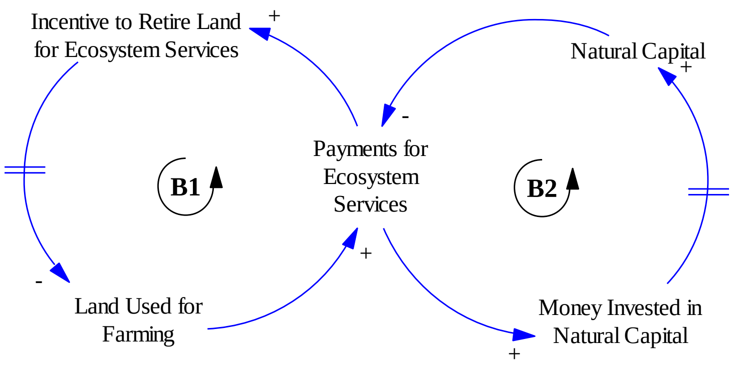

Figure 6 Finding the appropriate scale

Figure 6 shows a system in which farmers (or other producers) in a given area receive a payment for the ecosystem service for waste assimilation through for example riparian planting. The less pollution contributed to waterways, based on land use, the more they receive in payments for ecosystem services. Farmers with high ecosystem services payments will retire land which lessens their payments and increases natural capital. Over time, farmers will find the balance between profitability and sustainability.

1.6 Breaking the Investment Trap (Limits to Success)

The “Limits to Success” archetype is most often used to describe something that is constraining a company from achieving growth. We are using similar reinforcing and balancing loops to describe the breaking of a vicious cycle of investment and reinvestment (Figure 7). The investment trap is a reinforcing loop of investment in the protection of assets which ignores the underlying causes of the need to invest. Once the protection is in place, people feel secure and make additional investments. The subsequent increased value of investments requires further investment to protect. The balancing loop in this archetype represents the identification of leverage points elsewhere in the system to break that cycle, resulting in similar levels of protection without the need for on-going investment.

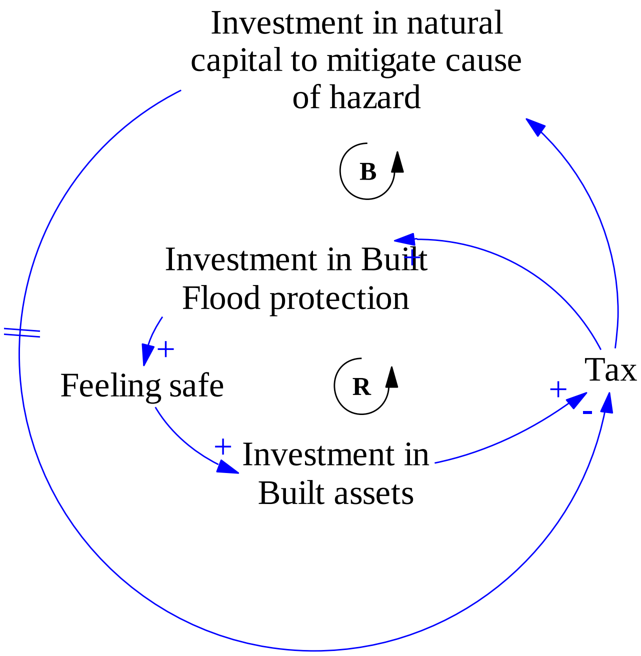

Figure 7 Breaking the Investment Trap

Built capital in Palmerston North is protected by stop-banks, constructed by the regional council, and periodically raised to mitigate the flood danger. This leads to land-owners in the city feeling secure and investing in more buildings and infrastructure as the population and economy of Palmerston North grows. Erosion from higher in the catchment has increased the height of the river bed and there is pressure on the council to increase the height of the stop-bank further, to protect the built capital in the city. This has become an investment trap (van den Belt et al., 2013b). A way to break this trap is replanting on hill country to prevent erosion. The effect would be to stop further sediment from washing downstream and allow sediment currently on hills to be washed away, allowing the level of the riverbed to stabilize, or recover. In this way the city would no longer need to spend a large portion of its annual budget on flood protection.

1.7 Long-term Investment in Natural Capital (Growth and Under Investment)

The change to the classical "Growth and Underinvestment" archetype is one of perspective. Senge's model warns about underinvestment and a business being too dominated by short-term decisions. The solutions-oriented archetype focusses on the long-term benefits for real gains. This is especially relevant for dealing with the intersection of business and ecology, as business decisions are often based on shorter-term returns and ignore the long-term implications of their business or land-use practices, affecting long term return on investments. By acknowledging and meeting long-term objectives and investments, the business or region can safe-guard themself for the future while also meeting short-term objectives.

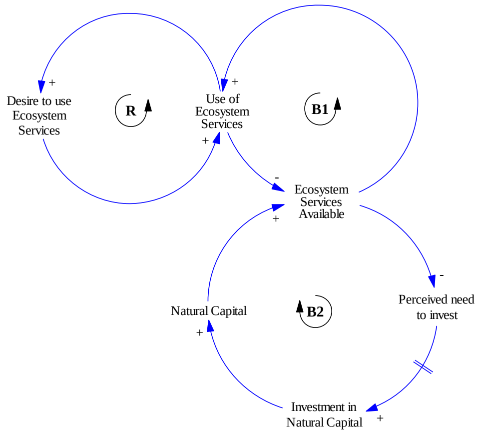

Figure 8 Long term investment in natural capital

As reported, water quality in the Manawatu River Catchment is poor and badly in need of improvement. There is little recreational use of the region's waterways, traditional Maori food harvesting is greatly diminished and there are very few opportunities for commercial enterprise based on the waterways. All of that would change significantly if there was an acknowledgement of the importance of natural capital to the region and the need to invest in it, as outlined in Figure 8.

1.8 Unexpected Dividends (Fixes the Fail)

One of the most often used of Senge's archetypes is "Fixes that Fail". These dynamics, from a solution-oriented perspective, can also reflect indirect benefits of an investment. For example, with forest restoration, there can be many benefits, some of them unexpected and only identified in retrospect, after land has been converted to natural capital. Similar to the Benefits of Collaboration archetype, this structure highlights the fact that the returns on investments often come in more than one form. Making potential positive side-effects explicit to stakeholders can help to convince them to commit to undertaking an alternative approach to their business or waste disposal practices.

In the transformed archetype (Figure 9), damage containment (e.g. better water quality) has led to a more desired location for housing (and more rate income) and more recreational activities. Both these outcomes have the flow-on effect of increasing support for more environmental restoration.

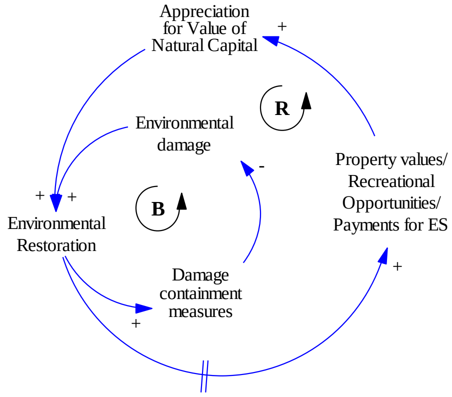

Figure 9 Unexpected Dividends

In the MRC, farmers are being encouraged, under the Sustainable Land-Use Initiative (SLUI) to fence off and plant riparian strips to protect rivers and to plant hilly terrain to protect against erosion. Farmers that take part in SLUI are often looking for other positive effects that it can bring. Some of those positive effects that have been identified are: windbreaks to help pasture growth; shelter for livestock; supplementary income from forestry; a source of free firewood; a more attractive landscape; easier farm management; a better place to play for children and grandchildren; real estate values. These additional benefits, when taken into consideration, can make the possibility of riparian protection and hill stabilisation more feasible.

1.9 Solution-oriented archetype decision tree

The solutions-oriented archetype decision tree (Figure 10) for the MRC allows stakeholders to create a narrative using the archetypes to work their way towards the generated vision.

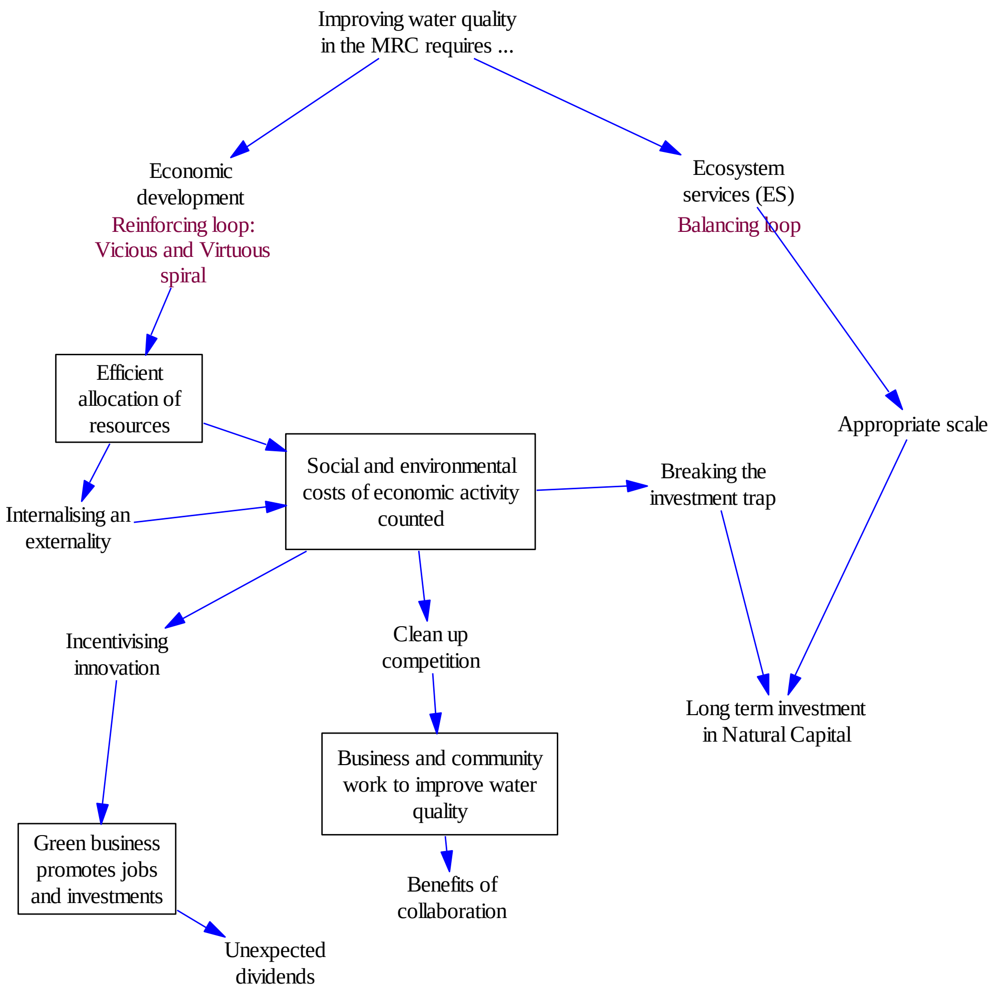

Figure 10 A decision tree linking archetypical CLD for a watershed

“Improving Water Quality in the Manawatu River requires ..”. The solutions-oriented archetype decision tree tells the story that both ‘Economic Development’ and ‘Ecosystem Services’ are required to achieve good water quality in a watershed as the MRC.

The right type of economic development can provide a virtuous reinforcing loop for ecosystem services and the basis for enhanced economic development. *Internalising an eternality* encourages more efficient allocation of resources as the full cost of production is taken into account (be it, economic, social or environmental). When the market place allocates resources to the most efficient use it maximises the scope for *Incentivising innovation*. If this innovation is directed towards technology that promotes good water quality (green technology) this can be sold elsewhere and provide *Unexpected dividends* to the local economy. Full cost of production accounting draws attention to the real costs associated with pollution. This can lead to *Clean-up competition* as improvements by one party highlights the extent to which others also pollute. As business and communities work together to improve water quality the *Benefits of collaboration* allow more to be achieved than could be done individually.

The ecosystem services part of the solutions-oriented archetype decision tree is a balancing loop as depletion constrains economic development. To ensure ecosystem services are maintained economic development has to be at an *appropriate scale*. Investing in natural capital to provide ecosystem services reduces the need for man-made infrastructure (for example flood banks and water treatment plants to replace wetlands). This is a way of *Breaking the investment trap* that requires continuous maintenance of, and investment in, man-made infrastructure. An appropriate level of *Long term investment in natural capital* means that the scale at which the economy operates (extended recreation, tourism provision) will increase as ecosystem services grow.

Discussion

The paper restructures archetypes focussing on problem behaviour in organizations, into solution-oriented archetypes for management of a catchment, investing in natural capital, from which ecosystem goods, services and benefits are derived.

The straight forward conversion to solution-oriented archetypes raises several challenges that warrant further exploration. Some challenges are related to the modelling, and some to the application of the models to the real-life scenario in the Manawatu River Catchment.

2.1 Challenges with the CLDs

Although most of our archetypes are based on Senge’s archetypes, and have the same configuration of reinforcing and balancing loops, it was necessary to change the configuration for “Tragedy of the Commons”. The idea was to change the model into something that showed the benefits of groups working together. In the modelling, it became clear that Senge’s “Tragedy of the Commons” can only tell the story of the failure of collective ownership, an appealing idea for decision-makers who seek to privatize common assets. That model prescribes a balancing loop to common effort and a reinforcing loop to individual effort and gain, which makes collective success under that model impossible. However, there are systems and examples, such as riparian planting, in which collective action achieves outcomes impossible for the individuals alone. The modelling revealed that the way to portray the positive effects of collaboration was to reverse the reinforcing and balancing loops.

2.2 Assumptions reflected in the examples

In Clean-up Competition (1.3), we are making the assumption that public scrutiny will be maintained over a long period. In some cases this may not be true. Without an interested public, local governments are likely to lack the political will to make difficult decision to deny consents and issue fines.

In Breaking the Investment Trap (1.6), the main barriers to this solution are convincing landowners to reforest part of their land, although the Sustainable Land Use Initiative (SLUI) (Dymond, 2010) is expected to generate a solid step in the right direction. See also van den Belt et al (in press 2013) describing a rudimentary system dynamics model of ‘flood protection: an investment trap between natural and built capital’.

2.3 Practicalities

The intention of these models is to extend visionary, inspiring ideas; stories of a desirable future for the watershed. Of course there will be many more factors that will need to be considered when actually implementing these (or similar) policies. Some of these considerations are discussed here.

The idea of Internalising an Externality (1.1) is simple and has been around for a long time. If the cost of clean-up can be added to the product and recovered to pay for the clean-up, it will incentivize customers to buy non-phosphorus-containing detergents. In reality, it faces several obstacles. Firstly, a local ordinance to add and recover a tariff on certain products may not be legal or enforceable as people could buy the products out of the region. Secondly, current laws in New Zealand do not require ingredients of non-food items to be labelled so identifying products containing phosphorus would be difficult. Thirdly, the cost of tariff collection might exceed the return.

Likewise, Incentivising Innovation (1.2) would certainly require councils to make adjustments to land-use plans. Local councils may need to change district plans to provide suitable land for conversion to waste treatment. It may also be more feasible for several manufacturers to share a facility, which would require an agreement over costs and management.

Finally, for Long-term Investment in Natural Capital (1.7), there is the question of who makes that investment. In the MRC, efforts to improve water quality often face issues of affordability. Town and city councils, especially smaller towns where the rate base is dwindling, have limited funds and are unlikely to have the luxury of taking the long-term view, although they clearly need to update their waste water treatment facilities. It may be necessary for the national government to support the long-term future of these towns and help to fund wastewater infrastructure.

2.4 Other possibilities

The example used for Finding the Appropriate Scale (1.5) involved charging farmers for waste disposal. In practice, this approach, in order not to be overly punitive on land-users who have farmed in a certain way for decades, could be used in conjunction with one-off or annual payments for farmers who have riparian areas, and subsidies for planting (an initiative currently being promoted in the catchment) and possibly carbon credits for carbon sequestration if strips are wide enough to qualify.

2.5 A Critique of Systems Thinking Archetypes

System dynamists are not all in agreement as to the usefulness of archetypes. They have been challenged on the basis that they are not capable of displaying the behaviour claimed (Homer 1996; Forrester, 1994). Sterman (2000) believes their use can lead to premature recognition of a problem, thus leading to thoughtless creation of counter-measures in a system. Concern has also been expressed that causal loop diagrams can be problematic in that they do not account for accumulations within a system (Sterman, 2000, Richardson, 1986). This criticism has not taken into account the use of delays in a causal loop diagram, which will offer insight into where accumulations may occur in a system. Whether or not a causal loop is moving in a clockwise or anti-clockwise direction, and the interaction between different loops of different directions in a systems archetype will give one an understanding of the speeds at which parts of the system will move in relation to the other parts, and the whole of the system; a reinforcing loop off the central loop will denote a quick system (as the reinforcing loop is acting like a 'catalyst') and a balancing loop will denote a more stable and slower system. It is necessary for the users of systems archetypes to understand, or at least attempt to gauge, the temporal scale of the system in question, so as to allow a system to reach equilibrium and avoid premature interference.

On the other side Lane (1998) argues that they can provide compelling insights. The fact that archetypes are the synthesis of much qualitative and quantitative modelling effort makes them a useful mechanism for accelerating learning and an effective device to share dynamic insights (Wolstenholme, 2003). Archetypes used in a collaborative / participatory context may elicit conversations crucial to align mental models (Vennix, 1999; van den Belt, 2004; Rouwette et al., 2002). This paper presents a qualitative systems thinking approach. To say the CLD's presented cannot be rejected would require quantitative system dynamics model to be built and run.

Conclusion

Given the great wealth of literature and research describing the mechanisms behind effective collaboration and decision-making processes, there is substantial reason to adopt the use of a solution-oriented archetype decision tree. Solutions generation, through the use of solution-oriented archetypes, in group settings may increase the exchanges of knowledge between individuals, as well as activate long-term intrinsic motivation.

Systems Thinking tools, particularly Causal Loop Diagrams have been praised for helping to make patterns and complex systems overt, enabling people to better manage the way they organise themselves and resources over which they have control. These tools are usually used to identify problems but the dynamics may be more powerful in the creation of a positive vision through the exploration of stories and reflect innovative, solution-oriented planning. The reframing of Senge's archetypes to reflect those dynamics offers a qualitative difference to systems thinking diagrams that would otherwise need to draw the problem and then fit the solution around the described problem. There is more interest in and less resistance to a positively-framed story than a fix for a negatively-framed one (personal experience, van den Belt). The solution-oriented archetypes can be more suitable for watershed management and encouraging than the classic archetypes, showing dynamics that environmental planners and innovators at times want to portray visually, such as identifying secondary benefits, balancing patterns of land-use and discouraging negative behaviours. As presented in this paper, solution-oriented archetypes can describe potential solutions of known problems, such as the pollution of the Manawatū River Catchment.

Acknowledgements

We are grateful for the funding made available by the New Zealand Ministry for Business, Innovation and Employment for the Integrated Freshwater Solutions project (MAUX1002), through which the graduate course Applied Ecological Economics is possible. This course provides an opportunity for students, stakeholders and faculty to jointly explore 'solutions' in different ways. This course would not be the same without the in-kind contributions from various stakeholders in the MRC.

References

Bardoel, E., & Haslett, T. (2004). Success to the Successful: The Use of Systems Thinking Tools in Teaching OB. *Organization Management Journal*, 1(2), 112-124.

Braun, W. (2002). The System Archetypes *The Systems Modeling Workbook*: Published online at: http://wwwu.uni-klu.ac.at/gossimit/pap/sd/wb_sysarch.pdf.

Brewer, E., Dunn, J., & Olszewski, P. (1988). Extrinsic Reward and Intrinsic Motivation: the vital link between classroom management and student performance. *Journal of Education for Teaching: International research and pedagogy*, 14(2), 151-170.

Dalkir, K., & Wiseman, E. (2004). Organizational Storytelling and Knowledge Management. *A Survey, Storytelling, Self, Society*: *An Interdisciplinary Journal of Storytelling Studies*, 1(1), 57-73.

Forrester JW. 1994. System dynamics, systems thinking and soft OR. *System Dynamics Review 10:245–256.*

Goodman, M. & Kliener, A. (1994) Using the Archetype Family Tree as a Diagnostic Tool. *The Systems Thinker*, December 1993/January 1994.

Hargreaves, B. (2002, Jan). *The Banks Peninsular Track: A Case Study in Rural Tourism.* Paper presented to the Pacific Rim Real Estate Society Conference, Christchurch. Retrieved from http://www.prres.net/Papers.

Homer JB. 1996. Why we iterate: scientific modelling in theory and practice. *System Dynamics Review 12: 1–19.*

Horsely, E. (2012, Sept 20) River cops city pollution. *Manawatu Standard*, Retrieved from http://www.stuff.co.nz/manawatu-standard.

Kang, S., Morris, S. & Snell, S. (2007). Relational archetypes, organizational learning, and value creation: Extending the human resource architecture. *Academy of Management Review*, 32(1), 236-256.

Kuhn, T. (1970). *The Structure of Scientific Revolutions* (2nd ed.). Chicago: University of Chicago Press.

Krippendorff, K. (2004). Intrinsic motivation and human-centred design. *Theoretical Issues in Ergonomics Science*, 5(1), 43-72.

Lane, D. (1998). Can we have confidence in Generic Structures? *The Journal of the Operational Research Society*, 49(9), 936-947.

Meadows, D. (1999). *Leverage Points. Places to Intervene in a System*. Hartland VT: The Sustainability Institute.

Mento, A., Jones, R., & Dirndorfer, W. (2002). A change management process: Grounded in both theory and practice. *Journal of Change Management,* 3(1), 45-59.

Morgan, J., & Burns, K. (2009, Nov 26) Manawatu River 'among worst in the West'. *Dominion Post*, p A1.

Rankin, J. (2011, July 18). Deterring the use of detergents. *Manawatu Standard.* Retrieved from http://www.stuff.co.nz/manawatu-standard.

Richardson, G.P. 1986/1976. Problems with Causal Loop Diagrams. *System Dynamics Review, 2 (2),158-170.*

Rouwette, E., Vennix, J., Mullekom, T (2002) Group Model building effectiveness: a review of assessment studies. *System Dynamics Review, 18 (1), 5-45.*

Schierlitz, C., Dymond, J., & Shepherd, J. (2006, Sept). *Erosion/sedimentation in the Manawatu catchment associated with Whole Farm Plans*. Contract Report: 0607/028, Palmerston North, New Zealand: Landcare Research.

Selart, M., Nordström, T., Kuvaas, B., & Takemura, K. (2008). Effects of Reward on Self-regulation, Intrinsic Motivation and Creativity. *Scandinavian Journal of Educational Research*, 52(5), 439-458.

Senge, P. (1990). *The fifth discipline: the art and practice of the learning organisation*. New York: Doubleday Currency.

Senge, P. M. (1994). *The Fifth discipline fieldbook : strategies and tools for building a learning organization / Peter M. Senge ... [et al.]*: New York : Currency, Doubleday, c1994.

Sterman, J.D. (2000). *Business dynamics: systems thinking and modelling for a complex word*. Boston, USA: Irwin/McGraw.

van den Belt, M., Schiele, H. & Forgie, V. (2013a). Integrated Freshwater Solutions – A New Zealand Application of Mediated Modeling. *Journal of the American Water Resources Association*.

van den Belt, M., Bowen, T., Slee, K., & Forgie, V. (2013b). Flood protection: Highlighting an investment trap between built and natural capital. *Journal of the American Water Resources Association*.

van den Belt, M. (2004). *Mediated Modeling - a system dynamics approach to environmental consensus building*. Washington: Island Press.

Vasi, I. (2007). Thinking Globally, Planning Nationally and Acting Locally: Nested Organizational Fields and Adoption of Environmental Practices. *Social Forces*, 86(1), 113–136.

Vennix, J. (1999) Group Model-building: tackling messy problems. *System Dynamics Review, 15 (4), 379-401.*

Watkins, K. & Marsick, J. (1992). Building the learning organisation: a new role for human resource developers. *Studies in Continuing Education*, 14(2), 115-129.

Wolstenholme, E. F. (2003). Towards the definition and use of a core set of archetypal structures in system dynamics. [Article]. *System Dynamics Review (Wiley), 19*(1), 7-26. doi: 10.1002/sdr.259.