MANAGING NATURAL AND PHYSICAL ASSETS FOR INTEGRATED OUTCOMES

Clare Feeney, Environment and Business Group; Christine Heremaia, Christchurch City Council; and Kathryn Scott, Landcare Research

ABSTRACT

This paper examines the management of surface waters and physical stormwater infrastructure in New Zealand in terms of the provisions of both the Resource Management Act 1991 (RMA) and the Local Government Act 2002 (LGA).

Explicit references to social, economic, environmental and cultural wellbeing are included in the purpose of the RMA in s5 and the LGA in s3. The RMA promotes the sustainable management of natural and physical (built/infrastructure assets) resources for the social, economic and cultural wellbeing of people and communities, while (among other things) safeguarding the life-supporting capacity of air, water soil and ecosystems. The LGA defines the role of local authorities to include promoting the social, economic, environmental and cultural well-being of their communities, taking a sustainable development approach.

The paper explores integrated approaches to managing and monitoring the natural resources that are a vital component of the physical urban stormwater infrastructure managed under the activity (asset) management provisions of the LGA. The natural and physical components of the infrastructure associated with urban water management may both be defined as infrastructure assets.

Managing this urban water-related natural and physical infrastructure also takes place within the context of integrated catchment management planning and network discharge consenting under the RMA. This opens up the possibilities for coordinating the inter-agency planning, management, maintenance and monitoring of natural and physical resources to achieve outcomes under the four wellbeings of both Acts in an integrated way.

Low impact urban design and development (LIUDD) case studies from Auckland and Christchurch are given to illustrate an approach to development that uses natural and physical infrastructure to reduce adverse environmental and other effects.

KEY WORDS

Asset management, catchment management, urban environment, community wellbeings, green infrastructure, grey infrastructure, Local Government Act, Resource Management Act, natural and physical resources, other legislation, outcomes, sustainability, values.

PRESENTER PROFILES

Christine Heremaia is a landscape planner with the Greenspace Team, Christchurch City Council, who has had extensive experience in surface water management. This includes broad scale planning associated with structure plans through to subdivision proposals and site design based on a values based approach, collaboration and integrated outcomes. She has been instrumental in overseeing the development and implementation of the Styx Vision 2000-2040, a long term river based community project.

Clare Feeney is a Director of Environmental Communications Ltd, a member of the Environment and Business Group (ebg), and has over twenty years experience in environmental management. She has expertise in a broad range of technical areas relating to water and soil management, integrated catchment management planning, sustainable all-waters management, riparian restoration in urban and rural settings, network discharge consents, integrated outcome monitoring across all four wellbeings (environmental, social, cultural and financial), pollution prevention and cleaner production/resource efficiency. Clare does environmental education and training for sectors including earthworks, manufacturing, construction, iwi, utilities and farming.

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1 INTRODUCTION

Public infrastructure delivers a range of community benefits ranging from the management of stormwater through to the provision of public open space and the protection of important ecological sites and landscape features. As these infrastructural assets provide the framework and support for the inner workings of a city, their design, condition and location influences the overall functioning of a city andhow individual community members perceive, experience and utilise the world around them.

In New Zealand, the development and management of public infrastructure is a core activity of local government. Legislation requires territorial councils to take a comprehensive and structured approach to the management of infrastructural assets, known as 'activity' (asset) management under the Local Government Act (2002). This must be done in a way that also achieves the purpose of the Resource Management Act (1991).

This paper explores the nature and management of public infrastructure associated with urban surface water management and public open space within this legislative framework.

2 LEGISLATIVE FRAMEWORK

The purpose of New Zealand's Resource Management Act 1991 (RMA) is set out in section 5 as being to promote the sustainable management of natural and physical resources. Section 2 defines natural and physical resources to include 'land, water, air, soil, minerals, and energy, all forms of plants and animals (whether native to New Zealand or introduced), and all structures'. Section 5 goes on to define sustainable management as 'managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural wellbeing and for their health and safety while sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and avoiding, remedying, or mitigating any adverse effects of activities on the environment.'

Under section 3 of the Local Government Act 2002 (LGA) regional and territorial councils must also promote the social, economic, environmental, and cultural well-being of their communities, taking a sustainable development approach. Sustainable development has been defined (Ministry for the Environment, 2002, p2) as:

- ensuring that all society's needs are met (as distinct from wants, needs are those essential inputs required to sustain human life)
- ensuring that all members of society have their needs met (in other words, equity in the use of resources)
- ensuring that all development is sustainable over time in a social, economic and environmental sense.

The LGA also requires councils to prepare plans (commonly called asset or activity management plans) for managing the various activities they carry out in order to provide services for their communities, such as water-related and other essential infrastructure.

Asset management is defined by the National Asset Management Steering (NAMS) Group (NAMS et al, 2006) as 'the combination of management, financial, economic, engineering, and other practices applied to physical assets with the objective of providing the required level of service in the most cost-effective way.' It means considering all management options and strategies as part of the asset lifecycle – that is, from planning to disposal.

Water-related infrastructure managed under the LGA has many effects on the natural environment as well as on the social, economic and cultural wellbeing of people and communities. Current stormwater asset management practices in New Zealand are informed by the Infrastructure Management Manual developed by the NAMS Group (NAMS et al, 2006). The Manual has set an internationally-recognized high standard of built asset management in New Zealand. Traditional asset management focuses on the number and condition of valves, manholes, pipes, inlets and kilometers of pipe and the levels of service they provide. However, the NAMS manual also explicitly recognizes (section 1) that infrastructure networks provide the platform for economic and social development, and are increasingly meeting recreational, artistic, and cultural needs of communities, as well as responding to the increasingly strict criteria of environmental regulators.

Many councils around New Zealand are currently updating their asset management plans and preparing integrated catchment management plans (ICMPs) in order to support consent applications to authorize under the RMA the discharges from their wastewater and stormwater networks into their ultimate freshwater or coastal receiving environments.

There are some differences in terminology between different parts of the LGA that set out how urban stormwater managers should approach their work. Section 124 of the LGA defines wastewater services as 'sewerage, treatment and disposal of sewage, and stormwater drainage' and s126 states that the territorial authority must describe how 'stormwater is disposed of within the district', set out the current and estimated future demands for water services within its district and state any issues relating to (among other things) the health and environmental impacts of discharges of stormwater and sewage (whether treated or untreated) arising from the current and future demands. However, s128 provides that in making a water and sanitary services assessment of current and future demands for water services and options to meet those demands, a territorial authority must consider 'the full range of options and their environmental and public health impacts, including (but not limited to) on-site collection and disposal; grey water and stormwater reuse or recycling; demand-reduction strategies, including public education, information, promotion of appropriate technologies, pricing, and regulation; the full range of technologies available; and any comments by the Medical Officer of Health.'

While the list in s128 covers matters well beyond the traditional focus of asset management plans, the items on it are not directly related back to the values enshrined in the four wellbeings of LGA s3 or RMA s5. However, s2 (1) (c) of LGA Schedule 10 requires the long-term council community plan (LTCCP) to outline any significant negative effects that any activity may have on the social, economic, environmental, or cultural well-being of the local community. Schedule 10 is silent on what will be done about these effects, presumably in deference to the RMA, but in s2 (1) (b) it requires the LTCCP to identify 'the community outcomes to which the group of activities primarily contributes'.

Nothing prevents a territorial authority or utility from consciously including all four wellbeings in its asset planning, building, operation, maintenance, replacement and monitoring, though it can be seen that this is not necessarily explicitly required under the activity management provisions of the LGA.

Nevertheless, due to the requirements to monitor the effects of an asset's operation under both RMA and LGA, it is de facto a mandatory requirement – and as the next sections will show, can inform regional and territorial councils' monitoring programs.

3 RESOURCES, INFRASTRUCTURE AND ASSETS: WHAT ARE THEY?

This section describes the natural and physical components of urban water systemsand some of the terms commonly used. In this paper we use the terms "natural and physical resources" as defined in the RMA, to refer to what may also be described as urban assets and urban infrastructure for the purposes of urban water management.

3.1 COMPONENTS OF URBAN WATER SYSTEMS

Urban surface water management systems and the associated public green space consist of natural and physical resources as defined in the RMA.

The components of the physical resource – the built infrastructure assets – are easily described and understood. Sometimes called 'grey' infrastructure (e.g. USEPA, 2008), they include elements such as stormwater inlets, pipes and outfalls, as well as things like bridges, signage, fencing, buildings and retaining walls. They have a defined life cycle, and their levels of service and the timing and funding of their maintenance, upgrade and replacement are set out in activity (asset) management plans. The need for and nature of maintenance, upgrade and replacement will be based on consideration of levels of service across all four wellbeings, and also whether or not a particular component has retained its purpose, value or cost-effectiveness across the wellbeings, including if it is no longer appropriate or can be used for another purpose (e.g. by being reused or recycled). Some structures will be built knowing that they are temporary in nature such as fencing around new plantings to protect them from damage by people or pest animals.

The components of the natural resource – sometimes called 'green' infrastructure (e.g. USEPA, 2008) – are easily listed but often less well understood and valued as 'assets' in the urban environment. They include soils and surface water bodies that retain, transport or receive urban runoff, including landforms such as floodplains. They also include the associated terrestrial and aquatic flora, fauna and ecosystems, as well as landscape and other aspects of social and cultural amenity. (Although this paper focuses on surface water management, we note that groundwater in particular can be easily overlooked, despite the sometimes large effects that built infrastructure can have on ground water recharge and flow direction. In some cases, for example, underground pipes may disrupt the flows of underground waters such as in peat, sand and gravel soils and this can divert recharge from one surface water body to another.)

Natural resources in the urban context also need to be managed, though differently from built ones. The approach taken will depend on their condition and whether or not they are managed primarily for their drainage ecological or social/cultural functions or a combination of these. Management for ecological values seeks to minimize human intervention in the long term through utilizing eco services by working with natural processes. If natural features are being managed primarily for their drainage or social/cultural values, then programmed human interventions will be required in both the short and long term. In both urban and rural contexts, historical decisions have resulted in waterways being extensively managed for drainage purposes. For example, the Christchurch District Drainage Board was established by an Act of Parliament in 1875 to deal with the disposal of surface water, waste water and sewage for that land draining toward the Estuary. As a result, the Avon, Heathcote, and Styx River systems were straightened and channelised to improve drainage until this Act was superseded by the RMA in 1991.

In summary, urban water systems comprise both natural and physical resources, to use the terminology of the RMA. Traditional built stormwater infrastructure comprises a reticulated network that sits within a natural network of surface and subsurface water bodies. These networks receive runoff from the land and discharge it into natural surface water bodies and, in some areas, into subsurface waters. Natural resources such as streams thus become an essential part of the physical stormwater conveyance system, while lakes, estuaries and coastal waters become the ultimate receiving environments.

These elements form a total whole. An integrated approach to both catchment and network management therefore means treating these natural and physical resources as one system, with stormwater managed as an integral component of all waters (the three piped and/or decentralized water networks and all forms of natural water, fresh and saline, surface and underground).

3.2 DESCRIBING URBAN WATER SYSTEMS AND ASSOCIATED RESOURCES

Asset and resource management are very much determined by people's appreciation and understanding of their functions and benefits. Using a variety of perspectives will provide a better overall understanding of natural and physical resources. Those associated with urban water management can be described in terms of the following attributes:

- values: abstract ideas about what a society believes to be good, right, and desirable
- place: a site, area, group of works or landscape, together with its associated structures, contents and surrounds. Such spatial descriptions enable an understanding of the interaction/relationship of different assets within the same space or locality
- system: reveals the inner workings of a landscape that are not necessarily visible (e.g. movement of water, energy, wildlife, people)
- measures used for quantifying purposes such as costings
- services: benefits to the community and the environment, including ecosystem services
- scores: a mark such as a number or letter indicating the quality associated with a particular attribute or range of assets.

Information on physical assets is well developed through the implementation of the NAMS methodology, and a number of councils are now starting to describe their natural assets in a similar manner, utilizing some of the methods described above and reflecting their organizations' statutory responsibilities and perspectives. Three examples are described below.

3.2.1 AUCKLAND CITY COUNCIL AND METROWATER

The Auckland City Council and Metrowater (2007) utilized values and scores to describe the city's waterways and thus determine their future management. They engaged NIWA to classify the waterways, which have been significantly modified by 150 years of urban development, but retain many values. Streams were divided into reaches with similar characteristics (e.g. concrete- vs grass or bush-lined and assigned a score of 1-10 based on their:

- drainage value: how important the stream is in getting stormwater away from houses, mainly based on the percentage of impervious surface in the catchment
- habitat value: the quality of the stream for supporting aquatic life, based on factors including stream bank vegetation, the naturalness of the stream bank and channel and the stream water and sediment quality

- public value: the contribution the stream makes to the city's character and amenity, including the accessibility of the stream, its size and the visual aesthetics of the stream channel and surrounds.

The scores were used to see how these values relate to each other along each stream and across the city – an important first step for the enhanced management of the watercourse. Some stream values compete with each other: for example, streams of high drainage value, conveying high stormwater flows, generally have artificial protection of their stream beds and banks to allow the stormwater to flow quickly and efficiently – but this leaves limited shelter for stream life, with correspondingly low habitat values. Auckland City and Metrowater will utilize their understanding of the city's watercourses within the context of an integrated management framework which recognizes their varied and sometimes competing functions and values.

3.2.2 AUCKLAND REGIONAL COUNCIL

The Auckland Regional Council (ARC) aimed to describe the ecological value of the region's waterways. In 2008 together with an expert panel of freshwater ecologists, it developed the stream ecological valuation (SEV), a method for scoring the ecological performance of streams. The SEV assesses the performance of 16 stream functions that were determined to be important in Auckland streams and that could be easily derived from field- or desk-based measurements. The SEV scores each of these functions on a scale of 0 to 1 and the overall SEV score is the mean of these 16 function scores. The 16 functions used to calculate the SEV score fall into four categories:

- hydraulic functions
  - natural flow regimes
  - connectivity to the natural flood-plain
  - connectivity for species migration
  - connectivity to groundwater
- biogeochemical functions
  - water temperature
  - dissolved oxygen levels
  - organic matter inputs
  - in-stream particle retention
  - de-contamination of pollutants
  - flood-plain particle retention
- habitat provision functions
  - fish spawning habitat
  - habitat for aquatic fauna
- biotic functions
  - fish fauna
  - invertebrate fauna
  - aquatic biodiversity
  - riparian vegetation.

Like the Auckland City/Metrowater classification, these functions enable stream and catchment managers to understand the different 'levels of service' a stream provides. The SEV can therefore be used:

- by the ARC to determine an environmental compensation ratio, an environmental benefit that compensates for a necessary environmental loss resulting from a consented activity which cannot be avoided, such as the permanent culverting of a watercourse
- by territorial authorities to assess the likely effectiveness of proposed stream management actions aimed at raising the 'level of service' of a stream or reach, and

to set priorities for stream restoration based on their cost and the ecological, social and cultural benefits.

3.2.3 NGATI WHATUA O ORAKEI

In an acknowledgement that the value of streams goes beyond the natural and physical and to get a better understanding of their cultural and historical values, Auckland City and Metrowater asked Ngati Whatua o Orakei to share their perspective and knowledge of five of the City's main streams. They focus on values, the spatial relationship of waterways with the wider catchment and the services that these waterways provide. The points below are excerpts from a summary of their work (Auckland City and Metrowater, 2007):

- the abundance of fresh water and good access to plentiful marine resources made Tamaki-makau-rau (Tamaki, the bride sought by a hundred suitors), the Auckland isthmus, a coveted area
- to Ngati Whatua, the history of the streams in Tamaki Makaurau is inseparable from the lands and catchments that surround them. The streams, their adjoining wetlands and surrounding volcanic soils provided Tangata whenua with abundant food and materials
- the mauri of the environment is an all-pervading aspect of Maori values. Mauri is considered the essence or life-force of all living things as well as minerals and chemicals like water or stone: it refers not only to their own life force, but to their ability to sustain the life of other things. The environment is therefore a fundamental component of Maori social and economic integrity and cultural identity
- for Maori, the loss and modification of streams and degradation of water quality causes a loss of mauri
- Ngati Whatua therefore favour a holistic ecosystem approach to managing streams that improves stream quality using natural systems and softer engineering techniques so that, together with appropriate recognition of the history and cultural significance of these important resources, the mauri of the streams and their contributing areas will gradually be restored.

3.3 SUMMARY AND IMPLICATIONS

Although they operate as one overall system, the natural and physical resources that comprise urban water systems are managed in accordance with two separate Acts, the RMA and the LGA.

The outcomes of this management are influenced by people's understanding of the resources. Assessments such as those summarized above are starting to utilize a range of descriptive methods and go much wider than just physical (built) resource management under the LGA, or just natural resource management under RMA. They also traverse the outcomes under all four wellbeings that both regional and territorial authorities must meet, including those required for the purposes of policy and plan outcome monitoring and the monitoring of the network discharge consents for which territorial authorities and utilities are applying.

In the next sections, we explore whether this broader understanding of natural and physical resources and integrating the requirements of the RMA and the LGA could enable greater sustainability to be achieved in terms of the four well beings.

4. ACHIEVING SUSTAINABILITY

4.1 A PROCESS

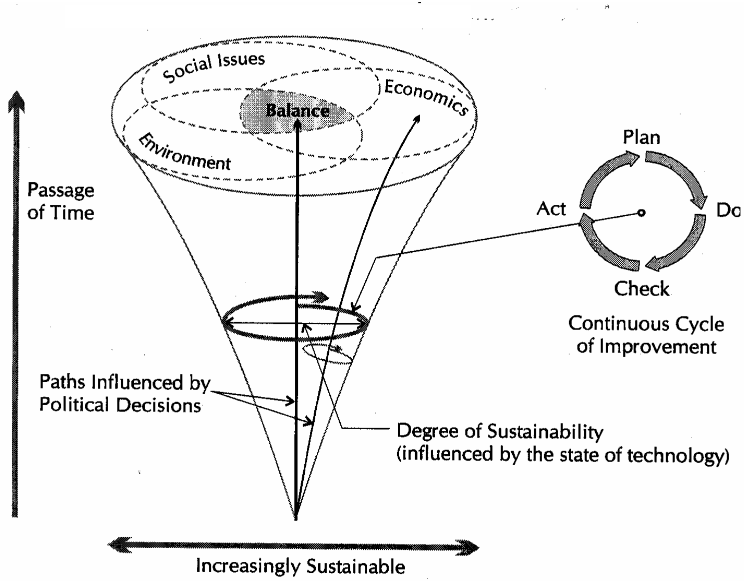
The word 'sustainability' is enshrined in the RMA and LGA and, in terms of the public infrastructure associated with surface water management and public open space, is given effect through the requirements in these two acts. In practice, however, the pathway to sustainability is not always so clear.

Fleming and Nott (2004, p2-3) state that irrespective of the definition used for sustainable development, it is fundamentally important to recognize (a) the interdependence of the environment, economy, and society, and (b) that sustained development is a journey and process of change.

This is very similar to the thinking of Taylor and Yates (2006), where community education and knowledge is essential to bringing environmental sustainability more directly into LGA processes. Figure 1 shows sustainable development as the pursuit of a balance between economic, social and environmental outcomes. It involves a process of adaptive management and continuous improvement, where technology and politics influence the degree of sustainability that is achieved, and this increases over time.

Figure 1 The sustainability whirlwind

Source: Flemming and Nott (2004)



Fleming and Nott (ibid) state that the challenge is to find and follow a course of action that enables progress from our current situation to our preferred (rather than probable) future. What constitutes a preferred future involves political decisions that are founded on expressed community values and aspirations, and an understanding of trade-offs with accounting against the 'triple bottom line'. Values, aspirations, trade-offs and decisions are clearly influenced by our state of knowledge. Building knowledge at all levels of society and the capacity to embrace change (rather than avoid it) is essential for sustainable development.

4.2 WORKING WITH NATURE AND COMMUNITIES

Lyle (1994, p10) states that sustainability requires a 'regenerative' system, one that provides for continuous replacement of energy and materials used in its operation through its own functional processes. Energy is replaced primarily by incoming solar radiation, while materials are replaced by recycling and reuse. Such a system generally has the following characteristics (ibid):

- operational integration with natural processes, and by extension with social processes
- minimum use of fossil fuels and artificial chemicals except for backup applications
- minimum use of non-renewable resources except where future reuse or recycling is possible and likely
- use of renewable resources within their capacity for renewal
- composition and volume of wastes within the capacity of the environment to reassimilate them without damage.

Figure 2 shows how this concept can be taken still further. Bill Reed (Integrative Design Collaborative Inc. et al, 2006) characterises the stages in the trajectory towards environmentally responsible design as:

1. Limiting the damage (still degenerating)
   - high performance design - design that realizes high efficiency and reduced impact in the building structure, operations, and site activities: this term implies a more technical efficiency approach to design and may limit an embrace of the larger natural system benefits
   - green design - a general term implying a direction of improvement in design- i.e. continual improvement towards a whole and healthy integration of human activities with natural systems - some people believe this is more applicable to buildings and technology
2. Neutral (not degenerating but not yet regenerating)
   - sustainable design – as with green design, the emphasis is on reaching a point of being able to sustain the health of the planet's organisms and systems over time. Sustainability is an inflection point where system health changes from degenerating to regenerating
3. Restorative (intervention to move towards system regeneration)
   - restorative design - this approach thinks about design in terms of using the activities of design and building to restore the capability of local natural systems to a healthy state of self organization (e.g., a local wetland, bush or riparian system)
4. Regenerative (systems are self- and other-sustaining)
   - regenerative design is a design process that engages the whole of the system of which we are part. This is place-based design. By engaging all the key stakeholders and processes of the place – humans, other biotic systems, earth systems, and the consciousness that connects and energizes them– the design process builds the capability of the people to engage in continuous and health creating relationships. There is continuous learning and feedback so that all aspects of the system are an integral part of the process of life in that place – co-evolution.

In practice, obtaining agreement on the relationship and balance between environment, society and the economy can cause tension and conflict within urban communities where land is at a premium. However the experience of Christchurch City is that incorporating natural processes and values into the management of public green space and waterway networks provides not only an opportunity to mitigate some of the adverse environmental effects of urban development, but also provides opportunities for regenerative design. Moreover it can also highlight and celebrate these processes and values within environments that are primarily human habitats, thereby contributing to a more sustainability-literate community.

Figure 2 The trajectory of environmentally responsible design

Source: Reed et al (Integrative Design Collaborative Inc., 2006)

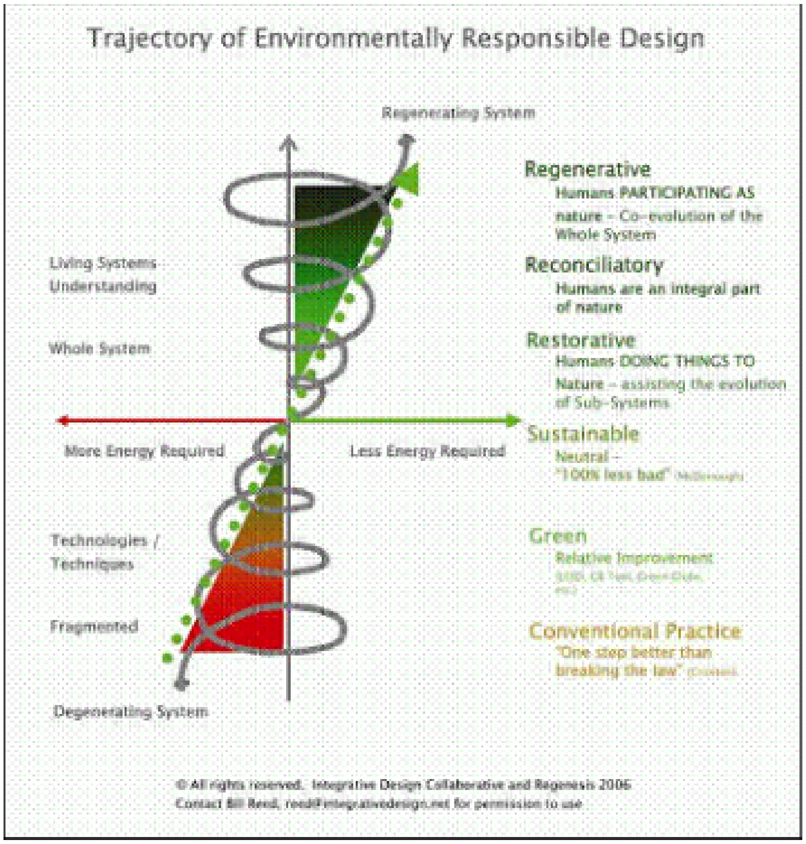
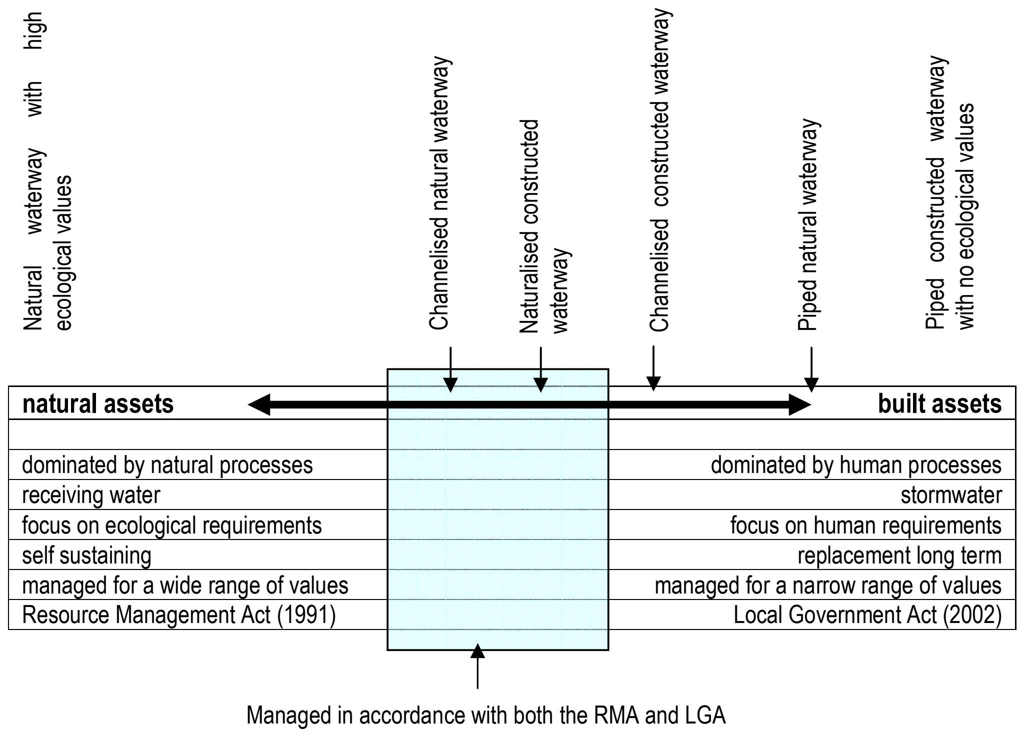


Figure 3 contrasts the RMA and the LGA views of urban waters, showing how we could draw them closer together if we consider both natural and physical resources as essential urban infrastructure that can be more sustainably managed. In the case of cities such as Christchurch (where many water-related urban environmental assets were constructed in order to drain the urban area) or in other areas (where streams had to be engineered to accommodate stormwater flows), it also provides guidance on how they could be managed to eventually become as ecologically valuable as existing natural waterways.

Figure 3   Urban water management under RMA and LGA



4.3 TOWARDS MORE SUSTAINABLE PHYSICAL RESOURCES

In the 2003 Budget, the Government provided for a stocktake to give an accurate snapshot of the state of New Zealand's transport, energy, telecommunications and water infrastructure. It also aimed to establish a better understanding of the links between infrastructure, sustainable development and growth and to establish principles to guide government decision-making. Four reports were produced in 2003-4 (available at http://www.med.govt.nz/templates/MultipageDocumentTOC____9191.aspx).

The report by PricewaterhouseCoopers (2004) contains a useful summary of national statistics for (among other infrastructure) reticulated water supply, surface and groundwater allocation and wastewater discharges, along with commentaries about their sustainability. It has less to say about stormwater, but comments (p 138) on the extent of uptake of 'integrated approaches to the management of water resources and associated infrastructure, such as the urban water cycle approach', wryly noting that 'a great distance still separates us from this vision' (Chapman et al, 2003).

Interestingly for those managing assets under the LGA, the report observes (p 244) that 'From a policy perspective, the legacy nature of the assets carries a number of implications. There are issues in terms of the value that should be ascribed to assets. Historical or acquisition cost is not necessarily a good measure of underlying value for assets which were acquired many years ago, but still have a useful economic life ahead of them. Depreciated replacement cost is not necessarily a good guide to value either if, in re-designing the system [by implication, from a sustainability point of view], the asset type, and their configuration would be much different to those in place today.'

The report by Chapman et al (2003) covers much information of considerable interest, and summarises water and wastewater infrastructure as well as irrigation under the following headings, which comprehensively address the four wellbeings under both RMA and LGA:

- the legacy of the past
- environmental aspects
- economic and eco-efficiency aspects
- social and cultural aspects
- sustainability issues
- key policy instruments.

Chapman et al (2003, p99ff) also comments on stormwater management under the heading 'Towards integrated urban water management' and note that the advanced age of existing infrastructure opens a 'window of opportunity' for reassessing past practices and design philosophies in light of key future trends.

Among these they identify (page 43 ff) the following trends for sustainable development and infrastructure:

- decarbonisation: the need to reduce fossil fuel emissions, which will affect transport technology and urban design as well as materials use, reflecting embodied energy content (see dematerialisation below)
- urban agglomeration and livability: the growing demand trend for more livable and walkable cities, increasingly needed by a health-conscious and aging population that is less able to drive cars
- immaterialisation: the demand for knowledge-based goods and services and pressure to replace goods with services
- dematerialisation: growing concern with waste volumes, energy and materials usage, and a desire to increase eco-efficiency and change consumption patterns
- decentralisation and scale reduction: building on innovative, small scale, distributed infrastructure technologies, including renewables
- increasing impact of environmental factors: the ecological and economic importance of being clean and green is increasingly acknowledged, so policies and management need to protect natural and cultural capital while allowing development
- integrated management: growing acknowledgement of cross-sectoral interactions (such as streams with stormwater infrastructure or roads with biodiversity).

Consideration of the above helps to identify desirable and undesirable cross-sectoral interactions and possible future-proofing needs. The authors note (ibid, p25) that "the benefits of joined-up thinking are easily overlooked. It is difficult to think 'outside the square', but sometimes major gains accrue from consideration of apparently unconnected developments, such as roading and wastewater. It is only now becoming apparent, for example, how low-impact urban design – including roading design – can reduce the need for costly infrastructure and improve social and environmental outcomes. Similarly, it is important that the funding assessment process and criteria for investment decisions take into account the full range of social, cultural and environmental considerations."

The following notes from the NZIER (2004) report are listed below as they reflect some of the issues that have arisen throughout the development of both asset and catchment management in New Zealand:

- [the Government's drive for] Sustainable development is not basically at odds with approaches to policy that have applied hitherto, provided the analysis does not leave out attributes important for sustainability. The principal attributes are: taking a longer term view of effects on future generations, and extending the boundaries of consideration beyond the immediate resources used in providing infrastructure. In policy terms, these are both types of 'externality', effects arising from a market failure, for which there is are established policy responses to be applied, if the effects are well defined. Long-standing approaches to policy analysis can include sustainability with modifications to policy appraisal and interpretation of results, achieving an integrated policy framework reflecting issues other than those commonly in economic frameworks (page i)

- the use of quadruple bottom line outcomes and multi-criteria analysis [that would cover the four wellbeings] is endorsed (p12-13) – although measures of achievement across the bottom lines should be set in broader policy settings rather than by infrastructure managers themselves, who monitor compliance with these (p13)
- problems in infrastructure's ability to contribute to maximising well-being over time includes failure to keep up with current or expected demands for the services it provides; failure of capacity to provide headroom or reserves to keep expected value of disruption by shocks to manageable levels; failure of capacity to adjust to megatrends like decarbonisation and persistence of unaddressed external effects
- causes of such failures include market dominance; information failures; co-ordination failures and failure to consider externalities and social objectives.

In the next section, we show how LIUDD is a way of adapting to the global trends for sustainable development and infrastructure identified by the Infrastructure Stocktake as well as those for restorative and regenerative design such as Fleming and Nott (2004, Taylor and Yates (2006) and Reed et al (2006).

4.4 THE EXAMPLE OF LOW IMPACT URBAN DESIGN AND DEVELOPMENT

Low impact urban design and development (LIUDD) may be considered as a solution that combines the use of physical resources (built infrastructure assets) and natural resources (soils, plants, underground waters, streams and other fresh and saline surface waters).

Sustainable development starts with design. Ideally, therefore, LIUDD starts with a catchment-scale biophysically-based design that builds on natural resources and landscape values. However, in greenfield developments, trying to protect existing landscape values associated with rural landscapes (e.g. open views and vistas) can be very difficult with the change to urban land uses. An alternative is to identify those features, processes, and elements that are important within existing landscapes. These are then protected and possibly restored through being incorporated into new urbanised areas leading to the development of new landscapes based on these values (Brunetta et al, 2008, p73). The identification and establishment of a 'blue/green' footprint incorporating natural features and processes such as floodplains and wetlands, together with stormwater infrastructure, can assist in this process.

Stormwater infrastructure in the LIUDD context will therefore be planned in the following sequence for a greenfield development:

- identify and protect the natural infrastructure and processes(soils, surface and underground waters, and associated flow paths and landforms)
- identify the contribution that decentralized infrastructure can make, such as green roofs, rain tanks, rain gardens and so on
- define the need for reticulated built stormwater infrastructure and maximise the use of biological systems such as swales, tree pits connected to pipes, engineered wetlands or ponds and the like.

Retrofit or brownfields situations can also be addressed, as is shown in the two case studies below.

4.4.1 GREENFIELD DEVELOPMENT: PAPANUI DRAIN, CHRISTCHURCH

Papanui Drain, a timber lined waterway with good flow from springs, was located between older residential development and rural land. The development of the rural land for housing for elderly persons resulted in the drain being reassessed in terms of the new values based approach. As it was inconsistent with new philosophy and no longer acceptable within new developments, the opportunity was taken to naturalise the waterway in terms of landscape, ecology, heritage, culture, recreation and drainage values. The acquisition of extra land, the creation of a new waterway based on ecological principles, and the development of a walkway linking into the existing walkway network has added an important landscape feature within the local community.

Figure 4 Naturalizing the Papanui Drain

prior to development *during construction* *naturalised waterway* *created ripple and pool*

4.4.2 RETROFIT: EDWARD STREET PROJECT

Edward Street, located in an older residential area of Christchurch, was frequently flooded during storm events. This was due to an inadequate stormwater pipe that ran underground within residential properties. Rather than replace and upgrade the existing pipe, a creative and collaborative approach involving an engineer, landscape architect, architect, artist and local residents produced a solution addressing the original issues and incorporating a range of added values. The solution involved relocating the pipe into the street as an open waterway. This stretch of the stormwater drainage system is no longer regarded as a utility, but is instead an important landscape feature within the wider landscape. The open waterway provides increased hydraulic capacity, artworks indicate the early wildlife that once occurred in this locality, additional planting will in time attract more birds to the area, the walkway has become popular with local residents, and the new road design slows down traffic. An assessment of the different options also identified this as the cheaper option.

Figure 5 The Edward Street Project

Street prior to development *After development* *During a storm event after development*

In summary, it can be seen that LIUDD in both greenfield and brownfield situations offers the opportunity to:

- maximise the value that natural resources can offer in terms of their performance for urban water management, moving towards the self-sustaining and regenerative systems summarized in section 4.3
- promote the sustainability performance of physical resources by incorporating natural processes, moving towards the more sustainable built infrastructure summarized in section 4.3.

The preceding sections show how the various legislative terms and processes fit together and can work together for greater sustainability. Table 1 lists these terms, showing how integrated catchment management plans and asset management plans effectively integrate the management of natural and physical resources, with LIUDD encouraging the use of more sustainable forms of urban water management that combine built, natural and bio-engineered assets.

Table 1 Integrated natural and physical resource management terms and concepts

natural resources	RMA	physical resources
integrated catchment management plans		asset management plans
natural assets (green infrastructure)	LGA	built assets (grey infrastructure)
totally natural	green engineering and biomimicry/LIUDD	totally built

The next section looks at how planning and monitoring systems can accommodate this integration.

4.5 PLANNING, MANAGEMENT AND MONITORING FOR JOINT INTEGRATED OUTCOMES UNDER RMA AND LGA

The NAMs manual has fostered increasingly sophisticated identification of different aspects of levels of service in terms of community wellbeing. It seems that the network consent process associated with stormwater discharges and the development of integrated catchment management plans is now encouraging the development of comparable understanding of their environmental and cultural outcomes. These developments have thus brought together some key territorial and regional council functions under the LGA and RMA.

Taylor and Yates (2006) consider processes such as these offer potential for communities to move towards stronger sustainability than through RMA processes alone, noting that:

- the LGA creates many opportunities for public participation in discussions about sustainable development, without defining how weak or strong the level of sustainability should be, thereby leaving potential for communities to move towards stronger sustainability
- education and knowledge of local communities and players is essential to bringing environmental sustainability more directly into LGA processes
- having stronger sustainability outcomes in LGA plans does not directly influence RMA processes such as regional or district plans or resource consents. Councils and communities must therefore repeat the process of interpreting and giving effect to their LGA sustainability outcomes under [contestable] RMA tools – this despite some opinions cited on p7 of this paper that the broader concept of sustainable development could lend RMA plans much-needed strategic direction.

One implication of such thinking could be that, for example in regional plans, environmental standards for land, water, and air, and standards and objectives for the other three wellbeings as they relate to these natural resources could be linked with levels of service in LTCCPs.

This would require co-ordination of the various levels of community aspiration for the environment as well as the other wellbeings, and agreement on how much the regional and constituent communities are willing to pay to achieve these.

The effects of urbanisation on land value also affects the ability of councils to pay for green infrastructure in the form of parks, coastal or riparian esplanade reserves, conservation areas and the like. While some can be provided by environmental compensation, or development contributions, the cost of acquiring a balance sufficient to provide healthy natural resource and ecosystem functioning may be prohibitive.

As natural and physical stormwater resources and all the waters in their natural watershed catchments are interconnected with and interdependent on each other, having stronger sustainability provisions in stormwater activity (asset) plans could contribute to improved sustainability outcomes. Where natural waterways are not considered part of the drainage network, asset plans focus on built infrastructure and meeting the LGA requirements, with detailed consideration of their effects on natural waters considered separately under the RMA consenting process. Dividing up stormwater management requirements in this way detracts from the value to be gained by integrating the management of the natural and physical water-related resources so as to achieve beneficial outcomes for all four wellbeings specified in each Act.

Introducing the four wellbeings into natural and physical resource management is facilitated by the use of two tools, both of which are widely used in urban stormwater and integrated catchment management:

- multi-criteria analysis (MCA)
- full life cycle analysis (LCA).

These analyses are summarised below to show how management of natural and built stormwater assets could move up the sustainability trajectory towards some of the sustainable infrastructure criteria set out in the Government's infrastructure Stocktake and towards regenerative design and LIUDD as summarised above, and also promote good outcome monitoring.

4.5.1 MULTI-CRITERIA ANALYSIS

Catchment and asset managers routinely consider the four wellbeings when assessing various management options in terms of their environmental and economic performance as well as their social and cultural acceptability. However their balancing of these considerations is not always well-documented, so the reasons for decisions and any trade-offs among the wellbeings that are made in arriving at them are not always available to inform future decision-making (Feeney and Trowsdale, 2007).

Multi-criteria analysis (MCA) is a tool to enable managers to choose or modify one or more options from multiple alternatives. The decision-making process is based on selection criteria that reflect the characteristics of the alternatives. MCA can be done with groups, and involving stakeholders in selecting options, defining criteria and assessing options is beneficial in that (Feeney and Kouwenhoven, 2008):

- decision makers, experts and stakeholders can all contribute
- it makes considerations explicit, informing the discussion
- both quantitative and qualitative information can be used
- very different options can be compared with each other

- it increases wider acceptance of the results
- it enables outcome monitoring to be done with respect to all four wellbeings.

The NAMS Group (2004) has developed a guideline for optimized decision-making and MCA is defined in section 4.5 (p4-10) as being 'well-suited to projects which have to be assessed in the basis of social, cultural, economic and environmental considerations.'

It can be seen that if catchment and asset managers select criteria that are easy to correlate with the four wellbeings under both RMA and LGA, this will promote integrated management and the monitoring and reporting they are required to do (see Table 1). This will be discussed in section 4.

4.5.2 LIFE-CYCLE ANALYSIS

Vesely et al (2005) in a paper on the economics of low impact stormwater management in practice, use the Australian and New Zealand Standard (AS/NZS 4536:1999) definition of life cycle costing, describing it as (p1) 'the process of assessing the cost of a product over its life cycle or portion thereof. Life cycle cost is defined as the sum of acquisition and ownership costs of an asset over its life cycle from design stage through manufacturing, use, maintenance and disposal.'

This analysis is very important for asset managers, because it helps them to distinguish between capital and operating costs, fund the depreciation of physical assets and set key management timeframes for asset inspection, maintenance, upgrade and replacement. Use of the NAMS manual ensures a rigorous analysis and that these important tasks are carried out very efficiently in order to meet the identified levels of service.

In terms of natural assets, careful consideration needs to be given how life cycle costs are assessed. Some natural assets are managed specifically for cultural values and human intervention will be an important component of their ongoing management and in time they will need to be replaced, for instance garden plantings, specimen trees, and lawn areas. With other natural assets, nature plays the dominant role. There is minimal human intervention, with actions limited to such activities as weed and pest control. They are self regenerating systems and therefore have no defined life cycle. This then impacts on depreciation and the ability to use the LGA to fund ongoing maintenance.

The Christchurch City Council has had to deal with this quandary. Christchurch's natural waterways are managed for drainage purposes, an LGA requirement, as well as being important natural assets. The Council has made a policy decision not to provide for depreciation on its natural and naturalized waterways, although there is funding for protection, restoration, ongoing maintenance and monitoring.

Although there are some differences in the management of natural and physical assets, could LGA asset management requirements inform and provide a strategic and robust framework for managing natural assets? This approach could provide a similar management framework for natural and physical resources in a given catchment, such as all types of water body affected by the operation of built assets, together with their associated terrestrial resources (riparian vegetation, green corridors, green links, coastal esplanades and reserves and so on). Native and other plantings, stream banks and stormwater outfalls all need inspection and maintenance if they are to continue to meet urban drainage as well as other community outcomes.

The MCA, together with an understanding of life cycle costs and management could provide a very robust management framework that could, for example, help to:

- define 'levels of service' for natural urban waters in terms of all four wellbeings

- ensure ongoing budget availability for asset inspection, maintenance and restoration
- enable comparison of costs and benefits associated with protecting existing natural features/assets, instead of creating new built structures or naturalized wetlands/ waterways that may need more ongoing maintenance and can never fully replace the complexity of the original
- identify cost-benefit opportunities for replacement of built infrastructure by natural infrastructure, for example by daylighting or otherwise naturalizing streams, or requiring the use of low impact measures from rooftop down in areas of growth or intensification, instead of installing new stormwater reticulation
- set more ambitious goals for regenerative and self-sustaining natural resources/assets with a minimal requirement for ongoing maintenance funding as they get to the point where natural processes really can take over.

MCA and LCA have the potential to provide a framework for considering all four wellbeings when managing and monitoring both natural and physical resources.

4.5.3 MONITORING PROGRESS TOWARDS SUSTAINABILITY

Better integration of planning, management and monitoring of natural and physical resources by regional and territorial councils under both the RMA and LGA – as well as under other legislation –is already happening to a greater degree as asset (activity) plans and catchment management plans are prepared in support of applications for network discharge consents.

Defining issues and outcomes is the start of the process. However the Auditor General (OAG, 2007a) found that despite some improvements, councils struggled to focus on the crucial issues facing them and define how they would address these in their Long Term Council-Community Plans (LTCCPs). He was 'surprised' and 'troubled' at the extent of the difficulty reported to him by local government representatives in gathering good information in order to identify community outcomes (see the Overview at www.oag.govt.nz/local-govt/ltccp/).

Moreover, other research has found that some of the staunchest supporters of protection of ecological values of waterways during consultation were local residents, iwi, conservation and community-based environmental restoration groups, yet these stakeholders were understood by civil servants as not having an interest in stormwater management (Scott, 2008).

The expert sustainable development reviewer (OAG, 2007b) also found it hard to assess the extent of integrated thinking across the four well-beings, and identified (p18) five main areas where effort should be placed to improve performance in relation to reflecting sustainable development within the LTCCP:

- raising both sector and auditor capability in regard to sustainable development, particularly in regard to long-term issues affecting future generations
- reflecting how the community outcomes discussion has occurred within the context of wellbeings for both current and future communities
- developing a coherent strategic performance framework driven from a sustainable development perspective and the community outcomes, for example, through meaningful descriptions of how activities contribute toward outcomes
- raising understanding of negative effects and communicating this meaningfully
- defining and infusing sustainable development through the planning processes of councils.

Other research (McNeill, 2007, 2008) has concluded that the public value of regional councils as the primary environmental policy and implementation agencies is low, with patchy capability and performance within and between layers of government, and an overall national deterioration of environmental conditions since 1989.

Taken together these findings strongly suggest that regional and territorial councils could better integrate their catchment and asset planning, management and monitoring in terms of the four wellbeings under both RMA and LGA. A lack of integrated outcomes within regions must inevitably affect the management and monitoring of natural and physical water-related assets within a catchment-based context intended to achieve sustainable outcomes across all four wellbeings.

As an example, regional policy statements are often very broad in scope and could usefully inform the framing of outcomes sought in LTCCPs and asset management plans. Working in a whole of catchment context would help identify issues and outcomes across all four wellbeings related to sustainable development and the sustainable management of natural and physical assets by regional and territorial councils.

For example, the USEPA (2008) identified the following environmental, economic, and human health benefits of green infrastructure, many of which go hand-in-hand with one another, including:

- stormwater pollutant reductions
- reduced sewer overflow events
- reduced and delayed stormwater runoff volume
- enhanced groundwater recharge
- increased carbon sequestration in plants and soils
- urban heat island mitigation and reduced energy demands by providing increased amounts of urban green space and vegetation
- improved air quality
- additional wildlife habitat and recreational space
- improved human health in terms of reduced levels of inner-city crime and violence, a stronger sense of community, improved academic performance, body mass and fitness
- increased land values of surrounding properties.

Chapman et al (2003, part 6, p121ff), examine infrastructure indicators, and endorse the use of the decoupling indicators proposed by Statistics New Zealand and the Ministry for the Environment (2002). However there seems little uptake of these so far, despite the valuable information they offer about progress towards sustainability. The term 'decoupling' refers to breaking the link between 'environmental bads' and 'economic goods', and decoupling environmental pressures from economic growth is one of the main objectives of the OECD Environmental Strategy for the First Decade of the 21st Century, adopted by OECD Environment Ministers in 2001 (OECD, 2001 and 2002), Decoupling indicators measure changes over time by using indicators that have an environmental pressure variable as the numerator and an economic variable as denominator.

Some decoupling indicators that could indicate whether stormwater asset plans and integrated catchment managment plans were generating the anticipated environmental and other results could be (from Feeney and Greenaway, 2007):

- ratio of impervious surface to length of natural stream

- ratio of piped to natural stormwater drainage density (green vs grey stormwater infrastructure)
- roading density v stream drainage density
- distributed / onsite services as a proportion of reticulated services
- percent of assets greened as part of renewal (e.g. streams daylighted instead of aging stormwater pipes being replaced)
- connectedness of areas of native vegetation as well as/in proportion to areal extent
- volume vs area of bulk earthworks
- ratio of pre- to post- development stream channel width and stream bank erosion.

Many of the indicators already collected by regional and territorial councils could be combined to produce useful decoupling indicators, and could also inform the development of broader quality of life or social/cultural wellbeing indicators.

This could usefully encompass related outcomes under other legislation, including the Health, Reserves, Conservation and Land Transport Management Acts.

A more integrated approach could help reconcile the tensions with differing terminology within and between the two Acts and the different management approaches for natural and physical (built/ infrastructural) resources, and show how integrated catchment and asset planning, management and monitoring in terms of the four wellbeings could be achieved.

Such an approach could help resolve the monitoring issued listed above, by using the plan preparation process set out in the RMA (as informed by the findings of the PUCM research team in Ericksen et al, 2003) together with the robust asset management processes in the NAMS Manual.

It would also identify practical steps that urban asset managers in city and district councils could take in their stormwater activity management plans to progressively achieve ecosystem and community resilience while enabling both sustainable development and sustainable resource management in the long term.

5. SUSTAINABILITY CHALLENGES

Built infrastructure needs ongoing maintenance, replacement and upgrading to meet ever-higher levels of service. Natural resources in cities also need ongoing maintenance, sometimes including replacement and enhancement – partly because of damage caused by the ongoing impacts of the operation of built infrastructure and community use; partly because it also needs to meet ever-higher levels of service as urban mangers understand the ecosystem, social, cultural and sometimes economic services it can provide; and partly because it may be too small or too impacted to become regenerative (self-sustaining).

The preceding discussion raises the following questions:

- what benefits would arise if councils managed the natural resources in a catchment under the LGA as if they were 'green infrastructure' assets?
- could the growing use of MCA and LCA in an approach similar to that set out in the NAMS Manual for physical resources inform a more strategic and robust framework for managing natural resources?
- could a more holistic, long term vision for sustainability such as regenerative design (Figure 2) foster the formulation of bolder holistic visions for all urban waters?

- could seeing the interconnectedness of all urban waters and built, natural and bioengineered infrastructure in a catchment promote the formulation of regenerative community outcomes? – outcomes that are more aspirational, less focused on physical asset maintenance and renewal within the current built, centralized paradigm, and aim to work sustainably with natural processes?
- could the use of sustainable infrastructure criteria that reflect all four wellbeings and decoupling indicators such as those listed in section 5.3 support the ongoing evolution of a regenerative way of seeing and managing all urban waters and their associated terrestrial values?
- could LCA and MCA provide a robust management framework that could, for example, help to:
  - define 'levels of service' for natural urban waters in terms of all four wellbeings
  - fund the 'depreciation' of natural resources affected by urban drainage in order to ensure ongoing budget availability for asset inspection, maintenance and replacement
  - identify cost-benefit opportunities for replacement of built infrastructure by natural infrastructure, for example by daylighting or otherwise naturalizing streams, or requiring the use of low impact measures from rooftop down in areas of growth or intensification, instead of installing new stormwater reticulation
  - set more ambitious goals for regenerative and self-sustaining natural resources/assets with a minimal requirement for ongoing maintenance funding as they get to the point where natural processes really can take over.
- could the above suggestions contribute to wider interagency integration of planning, management and monitoring of natural and physical resources under both the RMA and LGA?

6. SUMMARY AND CONCLUSIONS

Natural and physical resources are located in space and function as part of bigger systems and processes that are well synthesized in catchments – surface and subsurface.

Managing all waters as part of one system would see stormwater managed as an integral part of the three piped and/or decentralised networks and all forms of natural water. At present, stormwater management is divided up, with the built asset (physical resource) considered under the LGA, and natural waterways (including the effects of network discharges) considered under the RMA. More integrated management of the natural and physical water-related resources can be done if the levels of service of the physical resource (stormwater infrastructure asset) are defined in terms of outcomes that go across all four wellbeings and both Acts.

Better integration of planning, management and monitoring of stormwater-related natural and physical resources by regional and territorial councils under both the RMA and LGA – as well as under other legislation – is desirable because of their interconnectedness and the multiple outcomes for all four wellbeings that they deliver. This is already happening to a great degree as asset (activity) plans and catchment management plans are prepared in support of applications for network discharge consents. These help define the effects of the discharges from the asset for consenting purposes under the RMA (network discharge consents) which also requires consideration across the 4 wellbeings set out in s5 RMA, including the greater detail on environmental effects in s5.

In this paper we described the rigorous approach of the NAMS manual to the management of what the RMA calls 'physical resources' – using MCA and LCA, comparing capital and operating costs, funding the depreciation of physical assets and setting key management timeframes for asset inspection, maintenance, upgrade and replacement. We asked if a similar approach could inform a more strategic and robust framework for managing natural resources that are affected by urban development, and how green and grey infrastructure could both be managed more sustainably with the help of tools such as life cycle analysis and multi-criteria analysis.

We described some of the characteristics of sustainable infrastructure and sustainable development, and how natural and physical resource managers in regional and territorial councils are more explicitly addressing all four community wellbeings in their management of the adverse effects of urban development on water bodies. We then asked if a more holistic, long term vision for sustainability such as regenerative design as shown in Figure 2 could foster the formulation of bolder holistic visions for all urban waters. Could seeing green and grey infrastructure together in a catchment promote the formulation of restorative community outcomes – outcomes that were more aspirational, less focused on physical asset maintenance and renewal within the current built, centralized paradigm, and made better use of sustainable natural processes?

We concluded that outcomes from managing both natural and physical resources by both regional and territorial councils could be improved when they are coordinated and defined in terms of their performance across all four wellbeings under both the RMA and LGA

Such an approach could help monitor the performance of LIUDD, which (among other things) uses both reticulated and decentralised measures to reduce the adverse environmental effects of conventional development on the hydrological and related aquatic and terrestrial ecological functioning of catchments.

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