Low Impact Urban Design and Development Principles for Assessment of Planning, Policy and Development Outcomes

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Abstract

Every set of practices that is given a label requires clear definition including acknowledgement of inclusions and exclusions. Low Impact Urban Design and Development (LIUDD) is no exception. This paper provides a coded listing of principles, sub-principles and implementation actions that together define good LIUDD practice. It constitutes a coherent tool by which stakeholder groups can assess the relevance and uptake of LIUDD principles in plans, policies and practice. The paper is intended to differentiate this major New Zealand research and implementation programme, from other complementary programmes in the cluster of New Zealand 'Sustainable Cities' projects funded by the New Zealand Foundation for Research Science and Technology.

Acronyms

CUES	Centre for Urban Ecosystems Sustainability
LID	Low impact development
LIUDD	Low impact urban design and development
LIRRD	Low impact rural residential design and development
WSUD	Water sensitive urban design
FRST`	Foundation for Research, Science and Technology

Introduction

In late 2003, the Centre for Urban Ecosystem Sustainability (CUES) obtained almost six years of funding from the Foundation for Research, Science and Technology (FRST), on a competitive bid basis, to make Low Impact Urban Design and Development (LIUDD) mainstream practice throughout New Zealand. (CUES is a partnership between the University of Auckland and Landcare Research New Zealand Ltd.) An essential element of achieving this outcome is providing clarity to all stakeholders on what the principles of LIUDD are and the methods that can be used to implement those principles.

This paper has three main objectives. The first objective is to define what LIUDD is and what it is not, by defining principles and sub-principles (Table 1). The second objective is to show the relationship between the principles and implementation

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actions. The third objective is to code principles and implementation actions, thereby enabling a stakeholder to create a checklist of implementation achievements using these codes. Stakeholders will thereby be able to assess the degree to which their planning documents, policies, guidelines, codes of practice, and actual practices incorporate LIUDD. The paper elaborates on Table 1, which is the primary tool to do this, but it should not however be used in isolation. The application of LIUDD principles will require the reformulating of planning tools to promote and implement those principles (van Roon *et al*, 2005).

The evolution of LIUDD

LIUDD is a term unique to New Zealand and this FRST programme. Contributing philosophies, principles and practices are, however, common to many countries and cluster in various combinations under diverse labels.

Much has been written about sustainability, sustainable urban development and the need for different urban forms (e.g. Freeman and Thompson-Fawcett, 2003; de Roo and Millar, 2000; Duary and Plater-Zyberk, 1994; Jenks *et al,* 1996; PCE, 1998). While mostly at a general and conceptual level, various dimensions of sustainability are addressed, including environmental, economic, physical design, and social. The LIUDD approach uses ecological carrying capacity in a cyclical context as a starting point.

LIUDD evolved from its origins in Low Impact Development (LID, Shaver 2000) an alternative approach to stormwater management in North America. LID has much in common with Water Sensitive Urban Design (WSUD, Lloyd *et al*, 2001) in Australia. LID utilises natural drainage features in the landscape rather than piped systems for stormwater management and incorporates natural design features into erosion and sediment control during urban development (Shaver, 2000). WSUD, in addition, strongly emphasises 'integrated three waters management' to achieve reductions in water demand and sewage effluent discharges.

In New Zealand (Eason *et al*, 2004; van Roon, 2005) these concepts and practices, have been evolving since the late 1990s, and are reaching beyond alternative stormwater management to an integrated urban design and development process now termed LIUDD, which deliberately embraces LID as well as other elements. LIUDD aims to avoid a wide range of adverse effects of a physiochemical, biodiversity, social, economic and amenity nature, resulting from conventional urban development, protecting aquatic and terrestrial ecological integrity (van Roon and Knight, 2004) while allowing urbanisation at all densities.

The LIUDD team has drawn together sound New Zealand ecological principles for development (van Roon and Knight, 2004), New Zealand experience in green architecture (Vale and Vale, 2000), environmental economics (Krausse *et al.* 2001), alternative wastewater system design, and 'integrated three waters management'. ecovillage construction lessons (Gibellini, 2001), tikanga and maatauranga Maori (Harmsworth et al, 2002; Rolleston, 2005) urban/regional environmental planning knowledge, landscape restoration experience (Scott, 2003) and research into the design, management and maintenance of alternative stormwater management technologies (Pandey *et al*, 2003). This convergence and integration of disciplines,

and their application to case studies nationwide, continues to stimulate the evolution of LIUDD.

Not all of the Programme's work begins with the urban environment. Case studies in New Zealand locations particularly under pressure for peri-urban growth, for example Taupo, Manukau and Waiheke, have provided stimulus for development of Low Impact Rural Residential Design and Development (LIRRDD) principles and practices, some of which are reported in the appendix to the Proposed Taupo West Rural Structure Plan (TDC, 2004 Appendix 4).

The LIUDD approach is evolving rapidly and as research results become available and the nature of interactive systems are better understood, the emphasis in the Programme, articulated principles and means of implementation are adjusted. LIUDD and LIRRDD planning processes are seen as educational, to highlight the externalities which have tended to be ignored or under-rated in the process of design and development. With appropriate planning, funding and management, it is possible to have different patterns of development and intensities of development, whilst still meeting environmental standards and economic aspirations. In the past the concept of externalities has often been down played with the result that development has been subsidised by the environment to its detriment.

Principles of LIUDD

The principles, sub-principles and implementation tasks that we consider central to LIUDD (and LIRRDD) are summarized in Table 1 (Columns 1, 2 and 4 respectively). A detailed description of and rationale for each principle is presented in column 3 of the Table. The numerical codes, which follow implementation alternatives in the far-right column of Table 1, are provided to enable ease of reference to these tasks in future publications and checklists of LIUDD achievement. The inter-relationship of principles and sub-principles is also demonstrated in Figure 1. Note that in this figure, box outlines are differentiated to demonstrate the core focus of the LIUDD programme which is shown in bold text. Complementary tertiary principles and sub-principles, that are outside the LIUDD programme brief, are boxed-in by broken lines.

Table 1 includes some principles, which for the sake of completeness have been included, even though their implementation is beyond what we consider should be the scope of this LIUDD, FRST-funded programme. By including these extraneous sub-principles (XX) in the table we wish to convey the fact that we have not overlooked their importance in achieving objectives that arise from these principles. Instead we are acknowledging that their implementation belongs in other FRST funded 'Sustainable Cities' programmes (or in the existing statutory responsibilities of government agencies). In order to achieve a reasonably compact table, references have been minimised.

Maori values and practices have been incorporated throughout Table 1 as a first step in reframing development to create more sustainable forms of design from an indigenous/New Zealand perspective.

Note many of the principles can be mutually reinforcing or overarching. Each can be elaborated on in various ways and the implementation of one has spillover effects on

the others. These spillover effects can be both positive and negative. There will be instances in implementation situations where trade offs will be required and where more weight will have to be given to one principle over another.

Table 1 is a work in progress and is expected to change as the LIUDD Programme progresses. Change is expected to be least in the main principles. However, the implementation alternatives listed are the beginning of an evolving task and will be continually amended and updated. Also it is our intention in the next phase of the Programme to provide greater detail on all implementation alternatives and to explore their economic, social and regulatory implications.

Primary Principle

The principles in the left column of Table 1 form a hierarchy of importance. The single primary principle seeks recognition that human activity should respect and operate within natural cycles (van Roon and Knight, 2004) in order to minimize negative effects and optimize catchment internalisation of materials, contaminants and energy. This principle is embedded in all other principles in Table 1. The ecological carrying capacity concept, as part of resilient natural cycles, is central to the LIUDD approach.

Secondary Principles

Principle 2.1, concerning site selection, emphasises the fact that the greatest achievements in LIUDD and LIRRDD are derived from choosing the optimum location within a region for urban development (van Roon and Knight, 2004, p92). Without this essential step, even if the tertiary principles are applied consistently, there are unlikely to be acceptable outcomes. All principles in Table 1 provide useful guidance to this fundamental strategic planning approach. Sub-principle 2.1B articulates the 'least-regrets' approach as a component of site selection. The underlying philosophy of this sub-principle is to keep options open and avoid actions which pre-empt alternatives or which incur major costs.

Sub-principles 2.1X to 2.1XXX are critical components of site selection for development and hence are included in the table for completeness even though they fall outside the scope of this programme. As landscape quality and natural character are strongly influenced by natural cycles sub-principle 2.1X falls naturally in the hierarchy beneath the primary principle.

Principle 2.2 recognises past infrastructural investment and seeks to optimize return on this. It also addresses the services provided to society by healthy functional ecosystems and the need to ensure their ongoing capacity. The overarching secondary principle 2.3, concerning minimisation of imports and exports to a catchment, is generic to almost all tertiary principles.

Figure 1: Hierarchy of Principles of LIUDD. Principles in bold are the dominant focus of this LIUDD, FRST funded, programme. Principles in dashed boxes are complementary, but outside this programme. Figure 1 is a partial representation of Table 1 (van Roon and van Roon, 2005)

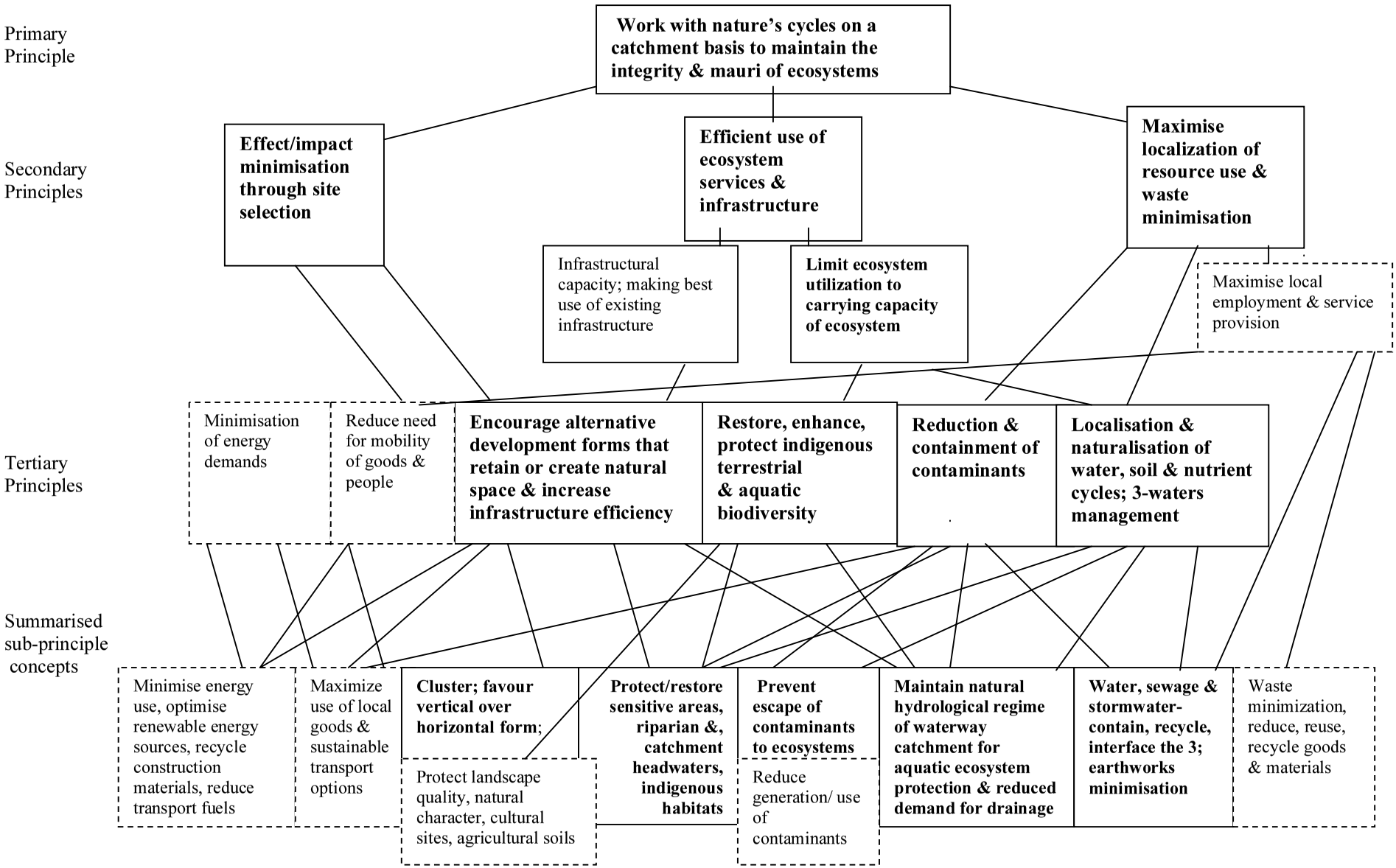

Table 1: CUES FRST funded LIUDD programme: checklist of LIUDD principles for assessment of planning, policy and development outcomes (van Roon, M & van Roon, H. 2005)
Sub-principles denoted by X or XX, rather than A - K, are not the focus of the LIUDD programme. By including these extraneous sub-principles in the table we wish to convey the fact that we have not overlooked their importance in achieving objectives that arise from these principles.

Principles	Sub-principles	Detailed description & Rationale	Examples of Implementation Alternatives
Primary principle 1 Work with nature's cycles on a catchment basis to maintain the integrity & mauri of ecosystems & minimise ecological footprints.	**Cycles & catchments** 1A Support cyclical ecological processes. 1B Use catchment context as design & management framework. 1C Recognise & provide for the long-term nature of natural cycles.	Use integrated knowledge systems including scientific and maatauranga Maori as bases to manage cyclical processes that determine distribution & influence of water, soil, plant nutrients, contaminants, organisms & energy. Human & cultural wellbeing are a significant by-product of the above being done effectively. Functionality of cyclical processes is essential for internalisation of effects & reduction of resource demand, that together make urban or rural-residential developments 'low impact'. Design within catchment context provides opportunities to support natural cycles (van Roon & Knight, 2004).	Use guidelines, district plan provisions, covenants, & the promotion of collaborative projects between, e.g. local government, community groups, tangata whenua, and private agencies that support natural ecosystem function, and promote effective management. Encourage recycling of water, wastes, materials & energy through co-location of complementary activities (1.1), innovative infrastructure (1.2) & technologies (1.3) preventing discharges to ecologically sensitive environments. Use catchment context for design & management (1.4).
Secondary principle **2.1**: Effect/impact minimisation through site selection.	**Spatial/Strategic Planning Approaches** **2.1A** Site selection used to avoid /minimize negative impacts thereby removing need for mitigation. **2.1B** Adopt 'least regrets' strategy to minimise risk. **2.1X** Protect sites of cultural significance. **2.1XX** Protect landscape quality & natural character.	Select areas for development & screen out inappropriate areas with avoidance of sensitive areas to minimise ecological, cultural & economic costs, as this is more effective then remedial work. The 'least regrets' approach provides a basis for remedial action, as a type of insurance policy, in case there are unforeseen consequences resulting from development. These are essential components of appropriate site selection for development.	Prior to development or re-development identify & delineate areas that are ecologically sensitive (2.1.1) & define limitations or constraints at a regional scale (2.1.2). Develop criteria for assessment & basis for decision-making in selection of development areas & convert to Regional Plan provisions (2.1.3) or District Strategic Plan provisions (2.1.4)[2]. Ensure the protection of culturally significant or culturally sensitive landscapes or sites for appropriate forms of design and development, where these values converge with or enhance natural processes or cycles (2.1.5). Whilst an integral part of wise site selection these are not elements of LIUDD FRST-funded programme. They may, however, benefit indirectly from the application of Principle 2.1 & other LIUDD principles. They are in fact key elements to achieving successful outcomes of the overall LIUDD process. Therefore, encourage appropriate forms of development and design in culturally and visually significant areas.
Secondary principle **2.2** Efficient use of ecosystem services & infrastructure	**Efficiency** **2.2A** Maintain ecosystems in optimum condition to ensure ongoing capacity to support human needs. **2.2B** Maximise use of existing infrastructure.	Degraded ecosystems lack the resilience & capacity to process wastes, accommodate resource extraction or otherwise cope with human use. The use of existing infrastructure is maximised so as to make best possible use of prior capital investment.	Develop & use economic instruments which price ecosystem services fairly and on an ongoing basis, taking account of all externalities including life cycle pricing (2.2.1). Provide comparative costing of ecosystem services versus conventional infrastructure, to achieve the same outcomes (2.2.2). Use this approach as a basis for the design & construction of alternative infrastructure (2.2.3).

[2] It could be argued that this could be generalised to 'plans and policy documents' but Regional and District are the 'spatial context'.

Secondary principle **2.3** Maximise localisation of resource use & waste minimisation.	**Localisation** **2.3A** Maximise containment of local water & contaminant cycles	Minimises impact on areas adjacent to catchment, reduces ecological footprint. Minimises downstream effects such as bioaccumulation in receiving waters.	Maximise use of local water (see below). Minimise contaminant export from catchment (2.3.1).
	2.3X Reduce, reuse, recycle goods & materials locally. **2.3XX** Maximise opportunities for local employment & service provision	Minimises impact on areas adjacent to catchment, reduces ecological footprint and energy consumption. Local energy capture & use is desirable from, for example, solar, wind & wave sources.	Not part of LIUDD programme brief.
Tertiary (3^0) principle **3.1:** Encourage alternative development forms that retain, restore or create natural space & increase infrastructure efficiency	**Plan in catchment context** **3.1A** Cluster activities whilst absolutely & permanently prohibiting intensification or structures on "balance" land. **3.1 B** Retrofit brownfield developments to encourage vertical over horizontal form & naturalise the resultant open space.	Concentration of compatible activities through clustering or vertical intensification can reduce capital costs, lowers ongoing maintenance & operating costs, whilst allowing for increased densities overall. It also facilitates the maintenance or restoration of natural hydrological regimes thereby protecting the integrity of aquatic ecosystems and reducing the demand for drainage construction and upgrading. Creation or retention of open space caters for amenity and recreational needs, human wellbeing needs, food production areas, catchment runoff protection and provides apportunities to protect and maintain culturally significant sites (e.g.,wahi tapu, mahinga kai, habitat of flora and fauna taonga).	Prior to development or re-development identify & delineate local areas that are ecologically significant (3.1.1) thereby defining limitations or constraints within the catchment (3.1.2). Similarly identify appropriate prime development locations (3.1.3) including areas with spare infrastructure capacity (3.1.4). Develop criteria for assessment & basis for decision-making in selection of development areas (3.1.5) & convert to District plan provisions (3.1.6) & covenanting (3.1.7) or other protective methods.
	3.1X Restore or enhance landscape quality & natural character.	As LIUDD principles are founded on working within nature's processes, improved landscape quality & natural character are certain byproducts of LIUDD approaches.	3.1X is not part of the LIUDD programme in its own right but its protection & enhancement are an integral byproduct of LIUDD approaches. In effect adequate provision for protection of landscape values will facilitate the effectiveness of the core programme.
	3.1XX Encourage appropriate forms of development & design in culturally significant areas where cultural values converge with natural cycles	For example, convergence of LIUDD principles with Maori values & concepts leads to a convergence of LIUDD structure plans & preferred development styles of urban Maori & tangata whenua groups. Culturally appropriate forms of LIUDD 'style' should be encouraged & followed in culturally sensitive areas (e.g. pa, marae, papa kainga, mahinga kai, and ngahere).	3.1XX is only indirectly aligned with the LIUDD programme but the inseparability of ecological & Maori cultural objectives means that in most such developments LIUDD principles will largely be adhered to.

3^0 principle **3.2:** Localisation & naturalisation of water, soil & nutrient cycles. Optimise recycling, minimise external demand & discharges. Optimise 'integrated three (or four) waters management' within local catchment.	**Stormwater** **3.2A** Minimise generation of stormwater, localise at source. **3.2B** Reduce 'effective' impervious surface area to less than 15% of catchment. **3.2C** Maintain/ re-create catchment flow characteristics as if under previous "natural vegetation" (hydrological neutrality). **3.2D** Utilise stormwater wherever possible as a secondary water supply **3.2E** Maximise groundwater recharge with stormwater following contaminant removal.	To identify what constitutes healthy waters based on scientific & cultural values. To ensure the natural functioning of healthy receiving waters, maintain the hydrological regime and water quality, minimize effects on the mauri, & avoid nutrient enrichment & contamination of kaimoana areas. Avoid capital costs & maintenance of reticulated systems. Minimize downstream surge & scour effects as well as trap contaminants & nutrients. Aim at zero discharge from properties. No development on upper & riparian catchment areas so as to ensure maintenance of the environment & water quality. Minimisation of runoff from catchment headwaters. Upper catchments act as reservoir for species to allow ongoing re-colonisations of habitat effected by development. Supported by sub-principles 3.2F to 3.2K	Use " natural processes" streams & wetlands as infrastructure (3.2.1). Avoid curb & channel storm water reticulation systems (3.2.2) & provide pipes only for overflows, not for base flow (3.2.3). Protection (3.2.4) & re-vegetation (3.2.5) of the riparian corridors. Identification, protection or re-creation of indigenous habitats, including wetlands, forests, springs, & streams - both perennial & ephemeral (3.2.6). Identification, protection, rehabilitation, re-creation, & maintenance of culturally significant natural areas e.g. mahinga kai, kaimoana, taonga (3.2.7). Provide financial, rating or other incentives to encourage developers & land owners to retain or create these natural features (3.2.8). Re-vegetate upper catchments (3.2.8) & all erosion prone areas (3.2.10). Encourage high biomass vegetation systems to trap rain & species with high evapo –transpiration capability (3.2.11). Adopt narrow roads (3.2.12), swales (3.2.13), rain gardens (3.2.14), biofiltration (3.2.15), porous paving (3.2.16), onsite detention tanks (3.2.17), ecoroofs (3.2.18). Provide for ongoing maintenance of stormwater control devices (3.2.19). Camber all impervious surfaces, including roads, to direct run-off to above devices or to natural vegetation areas on pervious soils (3.2.20). Use organic soils & compost to optimise function of raingardens (3.2.21). Protect & enable overland flow paths (3.2.22) & flood plains (3.2.23).
	Wastewater **3.2F** Minimize volume & recycle for dual water supply **3.2G** Nutrient strip sewage **3.2H** Encourage adoption of dry waste systems & reduced use of water-born systems.	Provide reticulated waste water systems or advanced treatment package plants. Adapt for improved environmental & cultural simultaneous outcomes, including waste water management sensitive to the values of Maori groups such as tangata whenua & urban Maori & by avoiding gradual cumulative unwanted effects of nutrient & contaminant buildup in waterways & soils, degradation of aquatic ecosystems, & loss of mauri.	Use of modern systems of Clivus multrum (3.2.24), compost toilets with flush pan (3.2.25), wetland treatment systems (3.2.26) as well as large scale sewage treatment plants with effluent recycling to land (3.2.27) or to dual water supply (3.2.28). Consider reticulated grey water systems (3.2.29) in lieu of full sewage reticulation.
	Water supply **3.2I** Minimise potable water usage & demand, reduce extraction from natural waterways. **3.2J** Harvest or recycle water	Reduce overall water use & utilize rainwater & recycled water for appropriate purposes as part of an overall approach. This provides the potential for savings in both treatment costs and the exposure of the human population & receiving water ecosystems to treatment chemicals.	Dual Water supply (3.2.30), use of water tanks (3.2.31) & water efficient appliances (3.2.32). Low flow tap fittings (3.2.33), recycle grey water for toilet & outside use 3.2.34). Gardens designed to favour indigenous vegetation adapted to local climate conditions (3.2.35). Provide systems which treat/sterilise rainwater for hot water use (3.2.36). Use of tailored plumbing systems to prevent cross-connection of potable & non-potable systems (3.2.37).

	Urban earthworks management **3.2K** Minimum site disturbance.	Respect the intactness of whenua (land). Avoid detrimental earthworks or management practices related to development, which have a significant (to be defined) impact on soil structure & the functioning of adjacent receiving waters & ecosystems. Minimum site disturbance; sediment containment - building sites. Minimise site works to reduce development costs & compaction problems. Carrying out subdivision & building site earthworks simultaneously is more economic, reduces compliance costs & facilitates monitoring & remedial work if needed.	Restrict earthworks on slopes identified in planning documents as unsuitable for development (3.2.38), and on significant ecological areas (3.2.39). Use techniques such as clustering to concentrate buildings on suitable soil types & slopes leaving areas naturally unsuitable for construction in a vegetated & undisturbed condition (3.2.40). Implementation of Principle 3.1 is supportive of these actions.
3^0 principle **3.3:** Reduction & containment of contaminants	**3.3X** Minimise generation of transport & industrial contaminants.	This would require changes in: transport modes & fuels: industrial processes, sustainable business, industrial ecology. This is the most effective means of reducing air, soil & stormwater contamination. Subprinciples 3.5X and 3.5A are supportive.	Not part of LIUDD programme brief.
	3.3XX Prevent /minimise escape of contaminants via atmosphere.	This is the most effective means of reducing air, soil & stormwater contamination.	Not part of LIUDD programme brief. This is implemented under the requirements & provisions of the Resource Management Act, 1991.
	3.3A Prevent escape of contaminants via water cycle.	Damage to ecosystems & human health reduced by containment.	Strip contaminants from stormwater before discharge to natural waterways (3.3.1).
	3.3B Reduce contaminant-loaded materials used in construction industry.	Damage to human health & ecosystems reduced by lower exposure to toxins in buildings/construction waste	Encourage the construction of 'green buildings' (3.3.2) Comply with requirements of the Building Act, 2004 (3.3.3.), building code (3.3.4) & council development construction guidelines (3.3.5).
3^0 principle **3.4:** Restore, enhance, protect indigenous, terrestrial & aquatic biodiversity.	**3.4A** Protect existing, restore or recreate indigenous habitats. No net loss of habitat. **3.4B** Protect &/or revegetate environmentally sensitive areas within catchment i.e. riparian corridors, steep slopes, ridgelines.	This supports the objectives of the NZ Biodiversity Strategy: promote natural ecosystem functioning within development catchments (e.g. by maintaining & enhancing water & soil cycles), maintain & enhance indigenous flora, fauna & habitats, recognise Maori aspirations to protect, rehabilitate & enhance indigenous ecosystems, reduce development pressures on indigenous biota.	Favour indigenous revegetation of stormwater management corridors with locally appropriate stock (3.4.1). Priority use of indigenous species when planting rain gardens, biofiltration systems & trees in swales (3.4.2). Provide incentives for indigenous vegetation planting (3.4.3) & retention on private lots (3.4.4). Maintain instream values to protect aquatic ecosystems from damage by structures (3.4.5) e.g. dams & culverts Promote biodiversity protection & restoration by iwi & hapu within Iwi Management Plans (3.4.6) & with support from Nga Whenua Rahui (3.4.7).

	3.4C Maintain or restore natural hydrological regime of waterway catchment for aquatic ecosystem protection.	Volumes & periodicity of discharges from catchments are determinants of habitat conditions in receiving water ecosystems including rivers, wetlands, lakes & estuaries. Changes to hydrological regime are determinants of major changes in aquatic ecosystem composition & function.	Retain (3.4.8), restore (3.4.9) or recreate (3.4.10) natural balance of vegetation cover, especially proportion of catchment in forest. Limit (greenfield, 3.4.11) or revert to (brownfield, 3.4.12) 'effective' impervious surface areas to <15% of catchment. Achieved also through implementation of principle 3.2A – E.
	3.4D Protect or restore appropriate riparian vegetation. Protect reservoir of species in catchment headwaters for stream recolonisation.	Riparian vegetation filters contaminants, provides shade for temperature control, bankside habitat & carbon supply. Headwaters terrestrial & stream habitats required for different life cycle stages.	Use covenants (3.4.13) or district plan provisions (3.4.14) to protect riparian strips. Use covenants (3.4.15) or district plan provisions (3.4.16) to protect headwater terrestrial-aquatic habitat combination.
3^0 principle **3.5:** Reduce need for mobility of goods & people.	**3.5X**. Maximise proximity of residential & employment bases. Optimise regional transport flows & public transport	Security, cost & availability of transport fuels are questionable. In addition to costs there is concern about air pollution & run-off quality. Favour rail & water-borne transport over road transport on environmental & economic efficiency grounds – low import of hydrocarbons to catchment.	Not part of LIUDD programme brief
	3.5XX Maximise local availability & use of: goods, services & neighbourhood sustainable transport options.	The sourcing of construction materials & food locally, reduces transport demand for goods & people. Compost generated locally could be input to raingardens for stormwater treatment (see 3.2.14). Riparian corridors protected or restored under sub-principle 3.4B provide space for cycling & walking paths. Note that implementation of these measures would achieve sub-principle 3.5 whilst supporting achievement of sub-principle 3.2B.	Not part of LIUDD programme brief

3^0 principle **3.6:** Minimisation of energy demands	**3.6A** Minimise Energy use	Improve building design for solar heat capture, insulation & use of passive solar energy & wind. Reduce imbedded energy in materials.	Double glazing (3.6.1) & high level insulation (3.6.2) for new & existing structures. Thermal mass/ materials in buildings for heat storage (3.6.3). House design to use (3.6.4) or avoid (3.6.5) solar input. Skylights (3.6.6) with or without link to fibre optics (3.6.7) for light transfer to other parts of building. Protect sunlight sight lines (3.6.8) for solar hot water, solar voltaics & passive solar heating.
	3.6X Optimise renewable energy sources **3.6XX** Reduce use of transport fuels **3.6XXX** Recycle construction materials	Reduces running costs to end user of energy. Reduces need to generate electricity & environmental impact thereof as well as transmission issues. Reduces travel costs. The sub-principles could be met by providing a residential access layout that minimizes the need for car travel & encourages non-mechanised transport options such as walking & cycling. This necessitates the creation of compact & functional urban areas with good public transport. Other provisions might include outside laundry drying areas, wind power generation as a permitted use, firewood tree cropping as an integral part of design/layout, local recycling depots/collection & composting areas as part of reducing energy-mobility requirements.	Not part of LIUDD programme brief

Maori terms used in Table 1 and this paper:

Maori: Indigenous people of New Zealand
tangata whenua: people of the land, used in reference to Maori associated with particular parts of New Zealand
mauri: The life force and unique personality of all things animate and inanimate.
rahui: a form of restriction set up over a resource by a hapu or its chief for spiritual, social, or economic reasons.
tikanga: customary correct ways of doing things
maatauranga Maori: traditional knowledge
whenua: land
wahi tapu: sacred place
urupa: burial ground
pa: fortified village
marae: meeting ground
papa kainga: village associated with a pa
mahinga kai: cultivation
ngahere: forest
waiora: healthy, clean water with high mauri
kaimoana: sea foods
iwi: Maori tribal groups
Nga whenua rahui: a fund to support voluntary protection of indigenous biodiversity on Maori land

Tertiary Principles

The justification for, and implementation of, tertiary principles in Table 1 are supported by an array of publications from this LIUDD programme and from parallel or complementary programmes in LID (Shaver, 2000) and WSUD. The hierarchical links between secondary principles, tertiary principles and sub-principles is demonstrated by Figure 1. Note that although we have demonstrated the increasing complexity of interactions with distance down the figure, there are numerous horizontal interactions at the tertiary and sub-principle levels that are not readily illustrated.

Principle 3.1 encourages alternative development forms so as to retain open space and enhance infrastructure efficiency. The term clustering, introduced in sub-principle 3.1A, is typically used to describe the grouping together of structures in specific locations on a common site. This works well in residential and rural-residential catchments. Clustering is not the only means of implementing Principle 3.1. For example, the concentration of titles (residential, commercial or industrial) within multi-level buildings instead of spread across a site can free-up open space between buildings that will then need to be protected from construction and re-vegetated to implement principles in Table 1. Such a change in site layout has as one of its primary objectives support for natural processes and biodiversity. This contrasts with the usual objective of maximizing human use and impervious surfaces on the site by covering it in buildings and car-parks. This approach has major implications for the implementation of LIUDD principles on all greenfield and redevelopment sites. Understanding and implementation of Principle 3.1 may be aided by similar approaches termed conservation subdivision implemented by Arendt (2004) in 23 states of the United States of America.

The stormwater sub-principles 3.2A to 3.2D inclusive and their implementation are the traditional focus of low impact approaches. Conviction of the need for (van Roon *et al*, 2004), and methods (NSCC, 2002) to achieve less than 15% 'effective' imperviousness, to ensure hydrological neutrality within a catchment, is a major challenge for all stakeholders but particularly those involved in redevelopment. Revegetation of riparian corridors is becoming mainstream practice but there is less awareness of the particular need to protect complementary terrestrial and stream ecosystems in catchment headwaters so that these can function as a reservoir of stream biota for re-colonisation of streams that become inadvertently degraded downstream (van Roon and Moore, 2004).

With regard to principle 3.2 we would like to emphasise the importance of 'integrated three (or four) waters management'. Linear once-through systems are minimized when water supply, wastewater and stormwater systems are designed and costed simultaneously to maximize opportunities for water recycling and the minimisation of natural water takings and effluent discharges. Such integration is similar to the principles of 'industrial ecology' whereby complementary industries co-locate so that the waste outputs of one industry become the raw material inputs of the next. A caution here, is that, the main centre of toxin accumulation that currently occurs in the aquatic receiving environment may move to the terrestrial environment. This LIUDD programme is limited in its influence upon contaminant generation. Through naturalization of the water cycle and support for green construction, the Programme

aims to contribute to the reduced use, mobility and ecosystem availability of contaminants.

The Programme (Principle 3.4) contributes to fulfillment of the objectives of New Zealand's Biodiversity Strategy (DoC and MfE, 2000) by encouraging optimum protection and re-vegetation of both urban and rural-residential areas (TDC 2004) and by reducing hydrological and aquatic biological changes (van Roon and Moore, 2004) brought about by urbanization. Direct habitat management that is embodied in tertiary principle 3.4 is just a minor component of the all-encompassing ecological objective encapsulated in LIUDD. The Programme as a whole addresses the optimum functioning of ecosystem processes and cycles upon which all life depends.

Transport management at the regional scale (Principle 3.5X) and waste minimisation are beyond the scope of this Programme. However transport management is acknowledged as a primary driver for site selection for urban use (Principle 2). Transport planning and management at the neighbourhood or catchment scale can comfortably be aligned with achievement of stormwater, biodiversity and neighbourhood containment objectives. Also aligned with these are energy conservation actions (Principle 3.6) implemented at neighbourhood and individual site scales.

In developing Table 1 we have been mindful of the need to provide balance in the provision of principles and methods relevant to brownfield as well as greenfield developments. Adoption of these methods for greenfield sites is relatively easier and faster than for brownfields. The retrofitting of existing New Zealand urban areas has typically only been achieved over many decades as individual sites have been redeveloped and infrastructure has required replacement.

Conclusions

We have attempted to define the principles and actions that make possible the implementation of LIUDD as defined by the Centre for Urban Ecosystem Sustainability, New Zealand. We have therefore created the means, by which all stakeholders involved in development processes can generate checklists using the codes we have provided, to document implementation achievements. It is hoped that this will bring greater clarity to stakeholders wishing to introduce LIUDD into everyday practice.

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