LOW IMPACT URBAN DESIGN AND DEVELOPMENT: MAKING IT MAINSTREAM

Charles Eason[1], Surya Pandey [1]Clare Feeney[2], Marjorie van Roon[3] and Jenny Dixon[3]
[1] Landcare Research, Private Bag 92170, Auckland
[2] Environment Business Group, P.O. Box 68440, Auckland
[3] Department of Planning, University of Auckland, Private Bag 92019, Auckland

The accelerating rate of urbanisation is putting tremendous pressure on ecosystems in and around our cities. Although basic health problems are largely resolved by utilising the European city panacea of extensive stormwater and wastewater piping, New Zealand is plagued by more sophisticated pollution problems that are citywide in nature. The challenge remains primarily in the area of stormwater and wastewater, but to these can be added site contamination, stream protection, site rehabilitation, terrain stability, and sediment management. This paper reviews the literature on low impact urban design and development and presents preliminary data on the utility of treatment walls and re-engineered soils to contain water, contaminants, and sediment. Evidence is also presented from stakeholder interviews to identify impediments to the implementation of these approaches.

INTRODUCTION

Rapid urban growth puts pressure on the capacities of natural resources and physical infrastructure (MfE, 2000). Both greenfields development and urban retrofitting lead to increasing demands on conventional infrastructure (e.g. energy, transport, reticulated pipe networks). The costs of maintaining existing and new systems using conventional design and engineering approaches are escalating. The Auckland region will be spending >NZ$5,000 million over the next 10 years to replace aging pipes and meet the demands of new development for water, wastewater and stormwater services alone (Manukau City Council website http://www.manukau.govt.nz/getinfo.htm). This investment in infrastructure will not, by itself, reduce adverse environmental impacts in the receiving estuaries and rivers since current development practices and infrastructure lead to continued adverse effects from stormwater runoff in urban areas. Contaminants and sediment reduce water quality, damaging streams and estuaries. While extensive piped systems remove discharges from the site, urban stormwater discharges (flow peaks and contaminants) are unpleasant and are degrading coastal and inland waterways (Curry, 1981; Williamson, 1991; Wilcock, 1994; Snelder & Trueman, 1995). Current approaches in environmental research focus on the entry, distribution and “end of pipe” monitoring of biological effects (Eason & O’Halloran, 2002), but have failed to put sufficient emphasis on mitigation or removal of the cause of these adverse effects.

Conventional approaches to residential land development in New Zealand substantially contribute to the problems (Basher, 2000; De Kimpe & Morel, 2000). In particular: (1) new subdivisions alter the land surface, significantly increasing impervious surfaces and compacting hard ground to the extent that there is a near-total loss of permeability after development (ARC, 2000; Basher, 2000; Zanders et al., 2002); (2) topsoil is commonly compacted or destroyed, washed away in storms, discarded into landfills, or sold, which increases the need for irrigation of gardens and green spaces and the cost of planting and restoration strategies (Zanders et al., 2002); (3) during infill housing, retrofitting and new development, impervious surfaces proliferate across whole districts, resulting in increased stormwater runoff and catchment-scale impacts (McConchie, 1992; Schueler, 1994; Arnold & Gibbons, 1996; Schreier & Brown, 2002).

In recent years as low-impact urban design and development (LIUDD) has been investigated in New Zealand, several issues have gained wider public recognition: worsening traffic congestion (especially in Auckland) and the difficulty of identifying more environmentally and economically affordable transport solutions; accumulation of contaminants in urban receiving waters; escalating costs of new and existing energy, water supply, wastewater and stormwater infrastructure; and deteriorating quality of housing stock and public health.

In this paper we review the literature, describe some results from preliminary testing of various LIUDD technologies, and report on stakeholder interviews conducted to identify impediments to LIUDD. Our discussion focuses on stormwater, although our current work recognises that truly sustainable urban development encompasses a wider range of environmental issues.

2. LITERATURE REVIEW OF LIUDD

Our review examined the literature on comparative assessments of sediment, pollution and flow discharges from LIUDD versus conventional building sites, and LIUDD versus conventional urban catchments. We have included in the review publications on the cost–benefit of the pollution-control infrastructure associated with LIUDD and conventional developments where possible.

LIUDD is based on both ecological (McHarg, 1969; Arendt et al., 1994; Hough, 1995; Steiner, 2000) and energy-efficient, compact approaches to urban design (Newman & Kenworthy, 1999). LIUDD comprises design and development practices that utilise natural systems and new low-impact technologies to avoid, minimise, and mitigate environmental damage. Key elements include working with nature to avoid or minimise impervious surfaces, utilising vegetation to assist in trapping pollutants and sediment, limiting earthworks, incorporating design features that reduce impacts, minimise waste, and enhance biodiversity. In addition, LIUDD can also be cost-effective by reducing the need for construction and regular renewal of physical assets, such as piping (CCC, 1999, 2000). Internationally, LIUDD initiatives are still comparatively new, with demonstration developments and elements of LIUDD in many cities (van Roon & Knight, 2003a,b).

van Roon & Knight (2003a) report that:

> *In North America, where LIUDD is in its infancy, there are elements of LIUDD in brownfield sites in Portland-Oregon (Liptan and Murase, 2002), Seattle (City of Seattle, 2002) and Massachusetts (Goldsmith, 2002). In western USA and throughout Canada, many greenfield sites (e.g. Simon*

Fraser University, Vancouver (CH2MHILL, 2002)) are at the design stage. Significant progress has been made by some councils in the writing of ordinances facilitating or requiring LIUDD (e.g. Cities of Olympia and Lacey, Washington) (City of Lacey, 2002; [E.] *Hielema* [City of Lacey pers. comm.], *2002; Holz, 2002). The Bureau of Environmental Services has established a range of brownfield projects throughout Portland City, Oregon, demonstrating infiltration gardens in carparks, and the successful use of ecoroofs and raingardens. These facilities are proving that a minimal discharge of stormwater from these sites is possible without infiltration to ground (Liptan and Murase, 2002).*

New York's water supply (Chichilnisky & Heal, 1998) is an example at the catchment scale of huge cost-savings achieved by working with natural systems once community support was elicited.

New Zealand has few examples of LIUDD. While soil information is recognised as an important component of urban planning (Basher, 2000), relative to permeability and erosion, the uptake of LIUDD is disappointing in view of the considerable technical knowledge and expertise in the design and application of LIUDD derived from overseas and New Zealand experience. Some Auckland councils, and other city councils in New Zealand, have recognised the opportunities for environmental protection and infrastructure cost-savings by producing a variety of comprehensive low-impact strategies and guidelines to encourage the use of swales, "raingardens", "roof-gardens", decreased imperviousness and other technology and strategies at the development site and catchment scale (NSCC, 2001, 2002; ACC, 2003; ARC, 2003a,b). Structure plans prepared by Auckland councils for greenfield sites show significant shifts toward LIUDD principles (e.g. for Long Bay; NSCC, 2002). However, developments are contingent on political willingness to implement relevant council plans and policies over a long time period. The Christchurch City *Waterways and Wetlands Natural Asset Management Strategy 1999* (CCC, 1999, 2000) is an early example of an innovative approach yet it is still not fully integrated with other council plans and strategies. Benefits from LIUDD are readily identified at a site level, although not all can be easily quantified.

2.1 Environmental performance

Compared with conventional development, LIUDD practices reduce sediment and pollutant loads, reduce stormwater flows, and have less impervious surface area and more vegetated areas. In turn, these lead to off-site benefits in waterways (improved fish habitat), in estuaries (improved habitat derived from reduced contaminant and sediment accumulation), and for terrestrial local biodiversity (native vegetation corridors).

Schueler (1994) reports reductions of 83% for sediments and approximately 70% for pollutants using LIUDD in North America. Monitoring data reported in Schueler (1994) indicate that LIUDD stormwater practices (ponds, wetlands, filters or infiltration practices) can reduce phosphorus loads by as much as 40–60%. Vegetated swales, an element of LIUDD, have been shown in a study in Austin, Texas, to be effective sedimentation/filtration systems for reducing concentrations and loads of contaminants in runoff from roads (Barrett et al., 1998). The percent reduction in pollutant mass transported to receiving waters was above 85% for suspended solids; 69–93% for turbidity, zinc and iron; and 36–61% for organic carbon, nitrate, phosphorus and lead.

2.2 Economic and financial issues

LIUDD has the potential to benefit all stakeholder groups through lower costs, improved environmental assets, and potentially improved returns to developers.

LIUDD has reduced energy requirements to less than 25% of conventional housing at a number of sites (BRESCO, 2000). "Bedzed" is a development of 100 dwellings in South London combining reduced energy requirements with reduced potable water demand (by 40%) through recycling of rain and wastewater (Shirley-Smith, 2002). LIUDD reduces infrastructure costs through the use of new design approaches and natural methods of stormwater avoidance and treatment. Auckland Regional Council (ARC, 2000) estimates low impact design approaches will deliver savings of approximately 10% of current stormwater infrastructure and maintenance costs – that is, a saving of $5 million per year by 2008 – with increased savings in the longer term. LIUDD incorporates vegetated waterways rather than pipes. The Christchurch *Waterways and Wetlands Natural Asset Management Strategy* (CCC, 1999, 2000) identified that restoration with natural drainage systems costs between NZ$30–1000 per metre compared with pipe replacement at NZ$500–1300 per metre, with the latter requiring higher maintenance costs and replacement after 150 years as well.

2.3 Other social benefits

LIUDD has the capacity to improve amenity values on- and off-site. LIUDD practices provide small, but significant, benefits to homeowners and the local community that have the potential to synergise with wider transport and public health initiatives:

- Streams are retained in natural states. Walking for fitness and enjoyment is the single most popular recreational activity in the Auckland region. Many people like to take frequent walks in their local area, and there is increasing demand for scenic interest – and therefore natural habitat – to be retained in new subdivisions (ARC, 1996).
- Native vegetation is retained where possible. Residential streets may be narrowed and curved but street corridors can remain wide to accommodate 'raingardens', large trees and swales. The existence of native vegetation on the properties is a frequent selling point.
- Ecological restoration in terms of urban form that is less colonial in style with restoration of native vegetation and traditional food sources will benefit Maori (indigenous people of New Zealand) and contribute to social and cultural restoration (Matunga, 2000).

3. TREATMENT TOOLS

Territorial and regional authorities in New Zealand have identified stormwater management as a priority environmental issue in urban areas, with increasing attention being paid to the use of various filter and natural systems to reduce the contaminant load in road runoff. In many cases, the effective application of such systems requires the development of improved filtration media and natural systems (such as raingardens), design and operational parameters (e.g. frequency of sediment or medium removal) to align construction, performance and maintenance to specific guidelines, such as those for stormwater interception devices as suggested by Auckland Regional Council in TP 10 (ARC, 2003b).

A variety of technologies are available to achieve a more sustainable approach to urban development. Here we report on results of recent research in New Zealand on treatment walls, raingardens, and ESA mapping.

Treatment walls

Landcare Research has been investigating the use of low-impact treatment technologies for the removal of pollutants in road runoff. In the past, we have examined five filter media under laboratory conditions to test their capacity to retain soluble pollutants (Pandey et al., 2003). Based on those laboratory results, four field studies have been established using the most promising substrate, or a combination of substrates, as the filter medium, intercepting runoff directly from a road or carpark.

The first filter was constructed at the corner of River Road and Wairere Drive in Hamilton in December 2000, to intercept the runoff from a portion of a roundabout. The filter medium consists of sphagnum/wood-ash (1:1 by volume, 1:10 by weight). In contrast to the Hamilton trial, in the second filter on the side of State Highway 1 in Cambridge, we are testing an increased ratio of sphagnum (20% by weight). Results from these two monitoring sites can be found in Pandey et al. (2003) and the sites are still being monitored. In the third study, at Henderson Recreation Centre in Waitakere City, three sand-filter chambers were modified to house sand (as per TP 10), Living Earth® green-waste compost (mixed with 20% sand) and Kinleith wood-ash as filter media. The results of this study can be found in Pandey et al. (2004). A fourth filter has recently been installed at Hewletts Road, Tauranga, treating runoff from a roundabout in an industrial area. Results from the Tauranga site can be found in Taylor et al. (2004).

Analyses of input concentrations of total acid-soluble copper, lead, and zinc; dissolved copper, lead, zinc, fluoranthene and pyrene; total suspended solids and pH in road runoff at the site in Tauranga are compared with those at three other New Zealand sites (Henderson, Cambridge and Hamilton) and from overseas studies in Table 1. Pollutant retention in different media from the Henderson study is shown in Table 2 and in the Tauranga treatment wall in Table 3.

A low-cost treatment wall (filter) solution to road runoff clearly meets a gap in knowledge or technology and has support from many end-users. These results confirm that treatment walls could be an effective tool to reduce contamination from road runoff, and are comparable to overseas studies (such as Schueler 1994), thereby benefiting not only the local environment, but also the wider receiving environment such as estuaries and coastal margins.

Table 1: Average concentrations (μg L^{-1} unless otherwise stated) of total acid-soluble copper, lead, and zinc, dissolved copper, lead, zinc, fluoranthene and pyrene, total suspended solids (TSS) and pH in road runoff from different sites

	Reference	Vehicles per day	Total Cu	Total Pb	Total Zn	Dissolved Cu	Dissolved Pb	Dissolved Zn	Dissolved fluoranthene	Dissolved pyrene	TSS (Mg L^{-1})	pH unit
Tauranga		24 000				3	1	64	0.17	0.03	337	6.4
Henderson summer						6	3	112	0.16	0.15	80	7.0
Henderson autumn/winter						3	1.1	51	0.04	0.03	50	7.3
Cambridge						7	3	230	0.13	0.03	99	7.1
Hamilton						16	10	121	0.04	0.02	101	7.2
Adelaide residential	Kumar et al., 2002	<1000				14	7	67			76	
Adelaide arterial	Kumar et al., 2002	>17 000				32	5	144			344	
Osaka	Shinya et al., 2000	75 000	66	34	648	12	6	93	0.03	0.02	63	
Paris residential	Gromaire-Mertz et al., 1999		61	133	550	17	4	138			93	
Nantes motorway	Legret & Pagotto, 1999	24 000	45	58	356	25	4	222			71	7.3
Bayreuth	Wust et al., 1994	25 000	149	224	373	53	5	74	0.51		224	7.9
Amsterdam	Berbee et al., 1999	53 000				31	2	108				
MoPac expressway	Barrett et al., 1998	8800	7	15	44						91	
MoPac expressway	Barrett et al., 1998	60 000	37	53	222						127	
Cincinnati	Sansalone & Buchberger, 1997	150 000	135	64	4274	93	16	4054				6.4

Table 2: Average (n = 6 over summer (S); 12 over autumn/winter (A/W)) concentrations (µg L^{-1}) of pollutants in input and output samples and percent retention through different media, Henderson (Waitakere City)

	Dissolved Cu		Dissolved Pb		Dissolved Zn		Dissolved fluoranthene		Dissolved pyrene	
	S	A/W	S	A/W	S	A/W	S	A/W	S	A/W
Input	6.1	2.7	3	1	112	51	0.164	0.043	0.145	0.034
Sand – Output	3.1	3.0	1	1	37	6	0.040	0.027	0.017	0.020
Sand – % retention	49	-12	56	–	67	88	76	38	89	42
Compost – Output	8.9	3.9	3	1	57	9	0.042	0.019	0.136	0.015
Compost % retention	-45	-45	2	–	49	82	74	56	6	56
Ash – Output	2.9	2.3	2	1	21	19	0.026	0.016	0.076	0.029
Ash – % retention	53	12	46	–	81	62	84	63	48	16

Table 3: Average concentrations (µg L^{-1}) of dissolved pollutants in input and output samples and percent retention in the treatment wall, Tauranga, after 6 months operation

	Dissolved Cu	Dissolved Pb	Dissolved Zn	Dissolved fluoranthene	Dissolved pyrene
Input	2.7	1.3	64.4	0.169	0.059
Output (replacement medium)	1.7	1.0	3.9	0.003	0.003
% retention	38.4	21.7	93.9	98.3	95.5

Raingardens

Engineered soil and plant systems have shown potential for retention and treatment of stormwater on available land within the constraints imposed by an urban built-environment. Raingardens comprise layers of gravel, sand, soil material and bark mulch combined with suitable native vegetation for functional and aesthetic value. Trials of soils' capacity for removing metals and phosphorus are reported in Soil Horizons (2003). Simulated stormwater flows (200 L) were applied to lysimeters (1 m diam. by 1.3 m high) packed with loamy Allophanic soil or clayey Ultic soil weekly for 6 months. Results confirm the value of soils for removing metals such as zinc. Clay is washed out of the weakly structured Ultic soil, producing a cloudy effluent with 40 mg/L suspended solids. Stormwater draining from the Allophanic soil is clear. The soils also differ in their ability to attenuate flow – the Ultic soil drains over 2–3 days; the Allophanic soil in 4 hours. These New Zealand results confirm that the efficacy of raingardens depends on the materials used in their construction. Hence the cost-effectiveness of raingardens as a treatment device will also depend on the availability of materials, and, for example, the cost of transporting soils to the site of the raingarden.

ESA mapping

Herald et al. (2003) report on work to compile a map of environmental sensitivity that integrates development constraints and opportunities to ensure optimum use of available land. These 'Environmentally Sensitive Area' or ESA maps link ecosystem units or landscape components in terms of their hydrological function and habitat requirements. Areas of opportunity, such as soils suitable for managing stormwater through infiltration, can be defined, as can areas unsuitable because of unstable slopes, natural flooding, or vulnerable ecosystems. These techniques enable a balance between urban development and environmental protection, and will allow planners, engineers and environmental scientists to develop common goals. The use of ESA mapping has the potential to facilitate greater integration of stormwater management, and enables urban engineers, planners and environmental scientists to work together to achieve a more effective urban development strategy.

A study completed by URS for Ecowater Solutions quantified contaminant contributions from stormwater and wastewater overflows from each of the 33 Stormwater Management Units (SMUs) in Waitakere City (URS, 2001). Contaminant loads were quantified in terms of an annual load from each land use defined within an SMU. Roads were a defined land use in this study. Study outcomes were used to identify SMUs with the highest contaminant contributions, with the intent of prioritising stormwater treatment in these SMUs. The study also identified SMUs where road runoff was a significant contributor to the overall SMU contaminant discharge. The summary data reviewed is presented in Table 4.

Table 4: Target stormwater management units (SMUs), roads and receiving environments in Waitakere City

SMU	Catchment size (ha)	Contributing roads (>10 000 cars per day)	Estimated road areas (ha)	Receiving environment
Central Park	235	Auckland/Kumeu Motorway, Lincoln Rd, Central Park Drive	29.4	Taikata
Lincoln	189	Lincoln Rd, Universal Drive	4	Taikata
Henderson Creek South	194	Railside Ave, Parrs and Bruce McLaren Rds	10.6	Taikata
Te Atatu Peninsula	491	Te Atatu Rd	6.6	Mid Waitemata
Te Atatu South	460	Te Atatu Rd, Great North Rd	13.6	Whau River
Wairau Creek	246	Great North Rd	1.2	Whau River
East New Lynn	342	Great North Rd, Rata St, Stock St, Olympic Park	11.86	Whau River
Avondale	419	Portage Rd	2	Whau River
Rewarewa	385	Titirangi Rd, Old Titirangi Rd	1.8	Whau River
Glen Eden	321	Pleasant & West Coast Rds	10.2	Whau River
Henderson Creek	194	Sel Peacock Dr., Great North & Edmonton Rds	13.8	Taikata
Lower Opanuku	488	Henderson Valley Rd	2.8	Taikata
Massey	539	Triangle Rd	8.2	Taikata

Waitakere City Council proposes to install a wide variety of stormwater treatment devices along major roads in order to mitigate the effect of road runoff on the receiving environments. The technologies outlined above may provide low-cost solutions to mitigate these adverse effects.

Regardless of their technical efficiency, the utility of these tools will be limited unless the demands of the various stakeholder groups are taken into account. To this end, we have conducted preliminary interviews to identify critical issues for key stakeholder groups in New Zealand's urban development.

4. PRELIMINARY INTERVIEWS

Preliminary interviews were conducted with six key stakeholder groups involved in urban development – consumers, community, developers, Maori, and regional and city councils – to identify impediments to LIUDD and opportunities for change.

Poor uptake of LIUDD results from many of the reasons summarised in Table 5. Interviews revealed that our six main stakeholder groups have specific needs that influence positively or negatively their willingness and ability to exploit LIUDD. When viewed collectively these conflicting needs are often perceived as competing or insurmountable impediments to change. Currently, disagreement and litigation between some key stakeholder groups can be costly and impede change.

Specific impediments can include price concerns, planning and institutional impediments. In New Zealand, there is a raft of council (local government) policies that influence environmental change. These plans are usually prepared under two key statutes, the Local Government Act 2002 and Resource Management Act 1991, although other acts and regulations also influence building developments. The suite of council policies and plans, including district plans, structure plans and codes of practice, along with the conservative practices of professionals, are often seen as key impediments to change. In New Zealand this is further compounded by a lack of locally based technical, hydrological and economic data in a form that is able to influence these plans and codes. However, we also see these mechanisms and stakeholders as key potential drivers for change towards sustainability.

To facilitate change by early adopters, innovative research and development is needed, complemented by new cost–benefit analyses of existing information, to modify and adapt LIUDD to local conditions. Environmental performance needs to be validated and development costs contained to bridge the current disjunction between performance and economic gain. For example, low cost housing may become slightly more expensive to build to sustainable standards, but this may be offset by lower infrastructure costs associated with LIUDD. Moreover, such housing may be more affordable to inhabit for those on lower incomes because of direct ongoing savings in energy and water use costs and indirect savings by avoiding or deferring public expenditure on a range of infrastructure services.

Table 5: Issues for major stakeholders relevant to low-impact urban design (LIUDD)

Community	Developers and professionals†	City council
Resistance to user pays and price increases	Lack of profit margins	Lack of data to define financial contribution/ incentives in district plans
Cross-subsidies	Council disincentives rather than incentives	Limited information to evaluate water cycle management options
Disassociation between user pays (water + waste) and local environmental quality	LIUDD subsidises city council infrastructure costs	Threat to revenue base if water supply and waste water systems are reduced
Dissatisfied with urban pollution	Rapid benefit/cost tools lacking	Maintenance cost
Higher quality of the environment	Short payback requirement	Biophysical data on land resilience, planting and biodiversity for district plan
Need for connectivity	Time commitment to absorb LIUDD manuals	Concern about disconnection between district plans that incorporate LIUDD & current engineering codes
Traffic, safety & congestion	RMA does not provide incentive	Regional council concerns about variability in district plan LIUDD content
Don't understand city or regional council LIUDD goals	Need to maximise land cover to maximise profit	Concern re misuse or misinterpretation of LIUDD
Consumer house prices, running costs	Consumer demand lacking	Need robust information to use in new guidelines for developers and regional plans
Unaware of choice	Lack of demonstration projects to emulate	Lack of understanding by community of goals
Vegetation, nature viewed as problematical	Risk to engineers who use non-conventional (piping) approaches	LIUDD needs to be tailored to different conditions and different council's needs (greenfield versus intensification).
Those who want LIUDD can't access skilled developers	*Maori*[**]	
Unaware that LIUDD will improve aesthetics & liveability	Maintaining low-cost housing imperative whilst meeting Maori values	
	Restoration and retro-fitting native vegetation	
	European identity predominates	
	Knowledge on restoration patchy	
	Waste of water and natural resources	
	Desire for LIUDD but developers not familiar with those approaches	

† professional = engineers, planners, architects
** based on discussion with Ngarimu Blair, Ngati Whatua o Orakei (and from Matunga, 2000)

5. SUMMARY

LIUDD is a critical means for achieving more sustainable growth. Many parts of the country are growing rapidly, with the Auckland region now identified as a priority focus in the Government's *Sustainable Development for NZ Programme for Action in Auckland* (New Zealand Government, 2002). However, implementation not only in Auckland but more widely is dependent on the willingness of a range of stakeholder groups to embrace principles of LIUDD.

New housing development provides different opportunities and challenges for different stakeholders (Dixon et al., 2001; Standards New Zealand, 2001; MfE, 2002). For developers, profit margins are tight, often at 5% or less (P. Rhodes, Hopper Developments, pers. comm. 2003). Our survey identified house price and household running costs as key issues for buyers; thus, changes to development practices to reduce environmental impacts must be at least cost-neutral. Councils want to reduce adverse environmental impacts but are constrained by the limited information available to underpin defensible rules to control development. City and district councils are concerned about rising infrastructure costs, which are exacerbated by design approaches that are costly to maintain. On one hand, urban communities expect traditional forms of infrastructure, such as kerbs, channels and extensive pavements, which reinforce current investment patterns by councils. On the other hand, these communities are demanding increasingly higher levels of environmental quality, such as clean streams and beaches (ACC, 2000), as well as increased numbers of native birds, and fish in streams (Heremaia, 2001).

The uptake of LIUDD may be influenced by a raft of instruments (including systems of charges and credits, public education, technical assistance and trading schemes) incorporated into statutory and non-statutory plans, strategies, and codes of practice administered by regional and city or district councils. Despite some very supportive codes (such as ARC, 2000, 2003b; ACC, 2003)) planning and regulatory processes are impeded by variable technical and economic information; poor integration across council policies, plans, and codes of practice (Beca Planning, 2001); as well as by lack of unity and buy-in from stakeholders.

There are also few incentives for change. Gathering the information needed to develop real incentives needs to be the focus for the future. Requirements include data on the relative importance and performance of improved low-impact development approaches (such as raingardens and treatment walls). As noted in section 3, the performance and cost-effectiveness will vary with local conditions, and at present there are limited New Zealand data. Hence, local research is critical in determining the best mix of approaches for a given area:

- to translate estimates of improved hydrological performance on development sites and reduced contaminant and stormwater loads from new development into economic values;
- to address the widespread variability and poor integration amongst different types of regulatory instruments (such as district plans and codes of practice);
- to incorporate wider dimensions of urban sustainability such as amenity, transport, energy and materials efficiency into development assessment criteria that make life easier for developers and regulators alike. These data will provide a platform for more rational development of incentives to facilitate the broad-scale adoption of low-impact urban development practices.

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