Auckland Unitary Plan Stormwater Management Provisions: Cost and Benefit Assessment - Appendix

December 2013 Technical Report 2013/043

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Auckland Unitary Plan Stormwater Management Provisions: Cost and Benefit Assessment - Appendix

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1.0 Appendix Structure

This Appendix provides the background information for the summary report on:

- Unit costs of stormwater management devices
- Cost and benefits assessment of Water Sensitive Design and Green Growth

This report discusses on-site stormwater management devices available on the market, along with their benefits and limitations. Whilst this report may name companies and/or products, the Auckland Council does not endorse any particular product or company. The naming of a product or company is purely to discuss the current methods available in the market. It is acknowledged that other products may be available (or have become available since the time of writing).

1.1 Unit Costs

Sections 2 through 8 detail the background information and assumptions made to determine the construction, on-going maintenance and total present costs for the following stormwater management devices:

- Section 2 - Bioretention
- Section 3 - Porous Paving
- Section 4 - Rain Water Tanks
- Section 5 - Living Roofs
- Section 6 - Sand Filters
- Section 7 – Wetlands
- Section 8 – Gravel Storage/Retention

1.2 Water Sensitive Design and Cost/Benefit Evaluation

Sections 9 through 11 provide background information on:

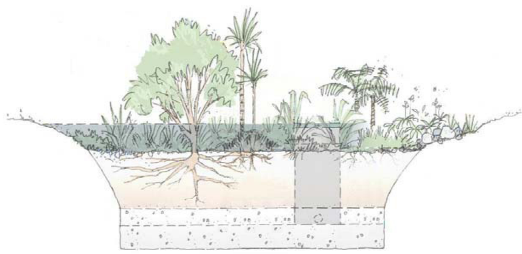
- Section 9 - Water Sensitive Design
- Section 10 - Benefits/Values
- Section 11 - Cost Benefit Analysis Case Studies

2.0 Bioretention

2.1 Introduction

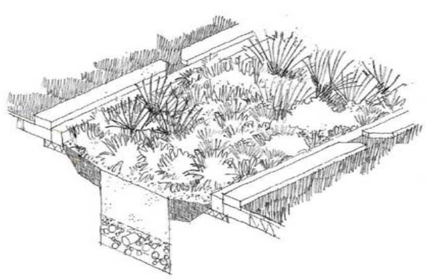
Bioretention systems slow stormwater flows and reduce the total volume of runoff primarily through transpiration and infiltration. The plants in in bioretention gardens transpire some of the water that is directed into the rain garden back into the atmosphere. For unlined rain gardens temporary storage of runoff in the planting media allows infiltration into the underlying soils. Bioretention gardens also provide water quality treatment through physical (sedimentation and filtration), chemical (adsorption) and biological (microbial action) mechanisms.

There is a wide range of bioretention devices including rain gardens, stormwater planters, tree pits and bioretention swales, refer schematics and brief descriptions below (Figure 2-1 to Figure 2-4, North Shore City Council 2008).



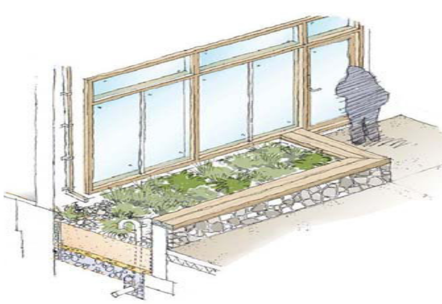
A rain garden is essentially a sunken garden with good well drained planting media and an underdrain to which stormwater is directed.

Figure 2-1 Typical Rain Garden Schematic (North Shore City Council 2008)



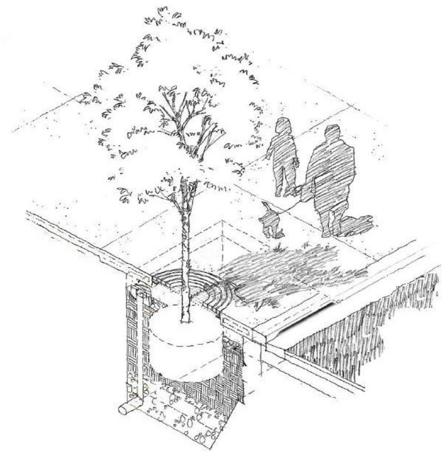
A bioretention swale is a long narrow sloping swale with a bio-retention system along the base of the swale. It can be used to convey as well as treat stormwater.

Figure 2-2 Bio-retention Swale Schematic (North Shore City Council 2008)



A stormwater planter is an above ground garden in a large container with a bioretention planting media and an underdrain to which stormwater is directed.

Figure 2-3 A Stormwater Planter Schematic (North Shore City Council 2008)



Tree pits which are used for planting of street trees can also be used for bioretention as long as they are designed to accommodate tree roots and with an appropriate underdrain system.

Figure 2-4 Tree Pit Schematic (North Shore City Council 2008)

Costs given below are primarily for the typical rain garden as presented in Figure 2-1 as these are the most commonly constructed. Costs for the bioretention swale would be similar if a similar cross-sectional depth of planting media and other components were used.

The stormwater planter is more of a structural device with costs being a function of the type and extent of the above ground storage system. Some indicative tree pit costs are included at the end of the chapter as these are gaining increased interest, particularly in confined paving areas.

2.2 Variability in Calculating Costs

Bio-retention costs are dependent on a number of factors, such as:

- Type of bioretention device - rain garden, bioretention swale, stormwater planter or tree pit.
- Size of device – there is a fixed cost for connections, pipes, inlet/outlet with a variable cost per m^2 for excavation, underdrain, planting media, mulch etc.
- Location of device – including access, ground slope, soil type, presence of existing drainage network, etc.
- Number of devices and type of construction activity – individual device construction and retrofitting can have significant cost penalties due to scale, mobilisation and establishment costs. Costs are less when multiple devices are installed as part of a larger subdivision activity.
- Depth of the rain garden – including the ponding depth, planting media, sand transition layer and underlying gravel layer.
- Need for an impermeable lining – in areas of slope instability an impermeable lining is required as infiltrating water into the subsoils can adversely affect slope stability.
- Amenity value – extent of planting and size of trees.
- Structural elements – for example, tree pits and stormwater planters may need concrete walls for structural support. Structural walls are optional for rain gardens and bio-retention swales (primarily dependent on adjacent traffic loading and available space).
- Maintenance costs are particularly hard to estimate due to their variability and lack of a documented data base due to their relatively new application in the Auckland area.

2.3 Costing Data Sources

Costing data below is presented for a range of different bio-retention devices.

Bio-retention Costing Data Sources include:

- West Harbour Raingarden retrofit preliminary design (total depth of 1.4m; comprising 1m of planting media, 0.15m of sand bed and 0.25m of gravel underdrain) – Engineers cost estimates based on detailed schedule of quantities (D&B Kettle Consulting Ltd 2008).
- Landcare Research COSTnz Model – itemised unit rates from the Landcare Research COSTnz Model (www.costnz.co.nz, November 2012). Used the West Harbour rain garden number 4 as an example for the Landcare cost data base for the comparison of schedule of items and costs. COSTnz data is based on rain garden design, construction and maintenance techniques at the time of model development (2006).
- Addison Development (The Avenues), Takanini – total of 42 rain gardens servicing a 14Ha residential development, total depth 1.0m; comprising 50mm mulch layer, 150mm topsoil layer, 500mm subsoil layer (1:1 peat to clean sand), 300mm scoria layer (Rhynd 2010, Cathy Bebelman Consulting Ltd 2006).
- Taurarua, Judges Bay – 89m^2 rain garden with timber baffles for sloping ground, total depth 1.0m; comprising 100mm stone mulch, 600mm filter media, geotextile layer, 300mm drainage layer constructed schedule of quantities plus 15% for design/construction documentation and consents.
- Long Bay, North Shore Auckland – 2012 as built costs provided for the Long Bay Development. Innovations in design, economy of scale (total of 86 rain gardens) and using a 'whole design' approach resulted in construction costs in the low end of the costs.

2.4 Construction Costs

2.4.1 Standard Rain Gardens

Table 2-1 summarises the construction costs for the range of different rain garden sizes (for up to 100m^2) from the West Harbour source and the other costing sources given above.

Table 2-1 Example Rain Garden Costs vs Water Surface Area

Rain garden ID	Water Surface Area (m^2)	Cost ($k)	Cost/m^2	Comments
West Harbour Rain Gardens designed for 28mm rain event				
1	100	$63,000	$630	
3	32	$20,000	$625	
4	30	$18,000	$600	
5	42	$20,000	$475	
6	35	$26,000	$745	
7	45	$22,000	$490	
8	52	$37,000	$712	

Rain garden ID	Water Surface Area (m^2)	Cost ($k)	Cost/m^2	Comments
West Harbour Rain Gardens designed for 10mm rain event				
2	60	$45,000	$750	
3	8	$12,000	$1,500	
4	8	$9,000	$1,125	
5	10	$11,000	$1,100	
Landcare Research COSTnz Model				
Using West Harbour 28mm rain event garden 4 quantities for comparison	30	15,000	$500	Low
		$19,200	$640	Middle
		25,000	$830	High
Addison Development, Takanini				
Average rain garden size	64	$33,300	$520	Using total estimated cost of $1.2M for 36 rain gardens, 4m width, and 16m average length.
Taurarua, Judges Bay				
Rain garden with baffles for sloping ground	89	$54,400	$620	Construction schedule of quantities plus 15% design/construction documents & consents.
Long Bay, North Shore, Auckland				
Off-line typical size for multiple devices in road reserves	18	$6,000	$330	Construction schedule of quantities for 86 rain gardens plus 15% design/construction documents & consents.

A schematic of the proposed West Harbour retrofit rain garden is presented in Figure 2-5.

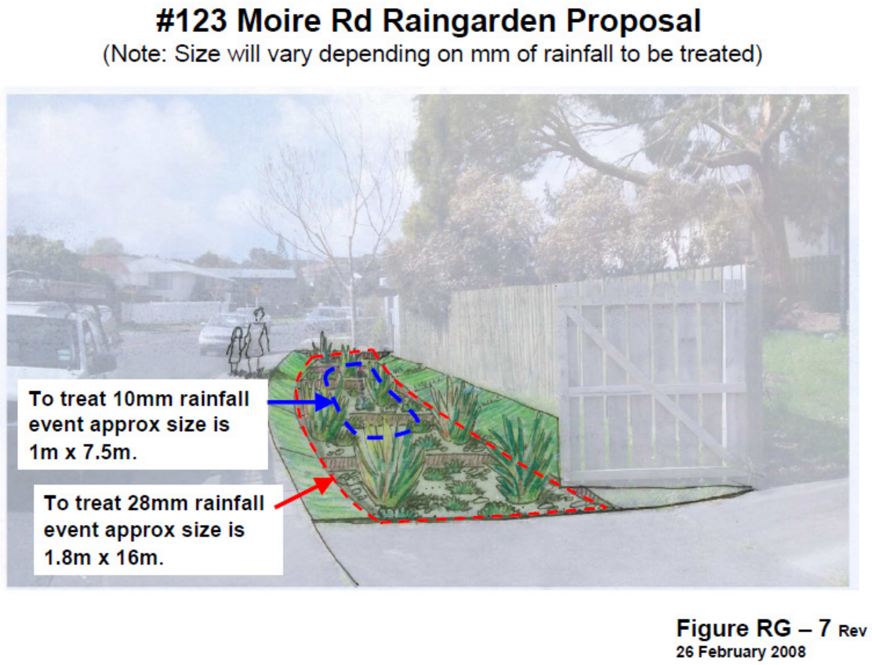


Figure 2-5 Schematic West Harbour Retrofit Rain Garden (D&B Kettle Consulting Ltd 2008)

A photograph of the rain gardens in the Addison Development, Takanini is presented in Figure 2-6. Runoff from paved and other surfaces is conveyed by swales and directly from adjacent road surfaces (via edge beams with a timber block sitting 30mm above the paved surface) through the rain garden into the primary piped network. Overflows that are greater than the rain garden design event is discharged into a manhole riser and grate.

Figure 2-6 Typical Addison Development Constructed Rain Garden (Rhynd 2010), reproduced with permission.

For sloping ground, up to 8% slope, baffles can be installed at intervals along the rain garden as shown in Figure 2-7.

Figure 2-7 Rain Garden with Baffles in Sloping Ground at Taurarua, Judges Bay Beach (D&B Kettle Consulting Ltd 2013b)

Of specific mention are the Long Bay rain gardens where innovation and cost savings are realised when the rain gardens are part of a 'whole design' approach and designed into the initial road layouts rather than as an 'add-on'. There were also efficiencies of scale with the construction of multiple rain gardens in Stage 1 of the Long Bay development which consisted of 86 rain gardens.

One of the conditions of the Long Bay development structure plan was for treatment of the road stormwater runoff within the road reserve with the use of bioretention and pervious paving for road grades up to 8%. The preferred method adopted by the developer was bioretention.

During the first stage of the development (constructed in 2012), the developer considered many options with the final selected construction method as follows (Wadan et al., 2013):

- Certified fill and lining – due to the parent soils sensitivity to instability from groundwater intrusion an additional measure of undercutting road alignments to 1 to 1.5m was undertaken during bulk earthworks to ensure the bioretention devices were bedded in certified fill, along with an impermeable lining. Lining selection was between a traditional LLDPE or a geo-synthetic clay liner. The geo-synthetic liner was chosen with its better performance and lower cost. The geo-synthetic liner, constructed using layers of bentonite clay was more 'malleable' than the LLDPE, could be laid directly onto drainage aggregate (the LLDPE needed protective geotextiles) and has the ability to 're-seal' if ruptured. The cost of the geo-synthetic liner was \$17 per m^2 compared to \$20 per m^2 for the LLDPE plus the additional \$8 per m^2 for the 2 layers of Bidim A44 geotextile. During construction the contractor was required to take photos of the installation at each stage of the works. See Figure 2-8 for photos of geo-synthetic liner.

Figure 2-8 Geo-synthetic liner installation (D&B Kettle Consulting Ltd 2013b)

- Another consideration was the closeness of the bioretention excavation to the adjacent road construction. It is important that the rain garden does not destabilise the structural integrity of the road basecourse layers and subgrade. In discussion with the project geotechnical engineers a combination of the 1 to 1.5m of road subgrade certified fill and 1V:1H side slopes of the rain garden excavation provided the necessary support to the road formation (refer Figure 2-9). Thus giving a typical rain garden size of about 2.7m wide and 6.7m long at its surface, and about 1.1m wide and 5.1m long at its base. The final rain garden geometry had a 200mm ponding depth above the mulch layer and 500mm depth of bio-filtration media to provide the necessary live storage and the trapezoidal design is capable of a storage volume of around 80% when compared to a rectangular vertical side slope design. These on-site rain gardens were part of a treatment train approach with further treatment in constructed wetlands.

Figure 2-9 Rain Garden Excavation (D&B Kettle Consulting Ltd 2013b)

- Another innovation was the design of the rain gardens as ‘off-line’ devices. Conventionally, rain gardens are designed with concrete manhole inlet structures to take the over-flows above the water quality rainfall event. This requires the construction of an expensive manhole structure ($1,500 to $2,000) and the disturbance of the mulch and planting from the flooding events flowing through the rain garden to the manhole inlet structure. The alternative ‘off-line’ arrangement utilised the cesspit in the adjacent road to act as the inlet structure for these larger flows. This offline design works by having kerb cutdowns designed for the water quality event (refer Figure 2-10 and Figure 2-11).

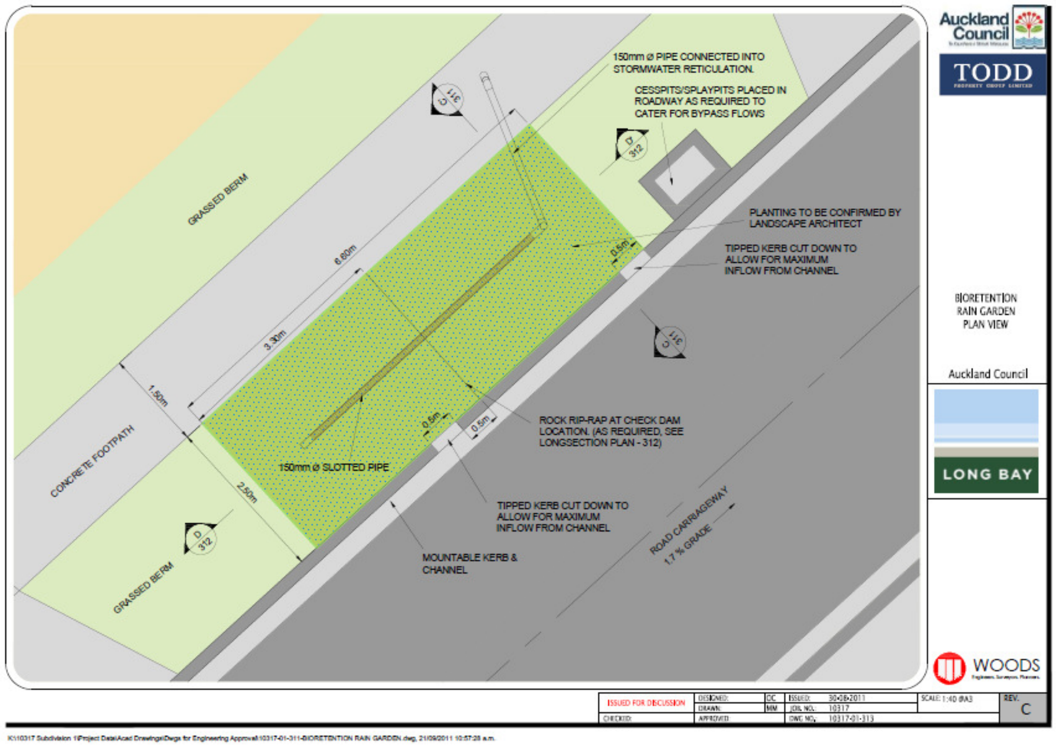


Figure 2-10 Typical Rain Garden Plan View (AECOM 2011)

Figure 2-11 Road cesspit downslope of kerb cutdow (D&B Kettle Consulting Ltd 2013b)

- The overall streetscape and long term maintenance was also an issue closely looked at. The developer chose fully planted verges with similar planting to the rain garden areas to give a consistent look to the berms. Whilst the council initially had concerns with regards to the on-going maintenance costs of fully planted berms versus standard grass verges, they were convinced that planted berms were plausible once shown that the amount of additional maintenance required was insignificant (Wadan et al., 2013).

The above Long Bay rain garden innovations, coupled with the efficiencies of the number of rain gardens (86 rain gardens with an average size of $15m^2$, for a total rain garden area of $1,330m^2$) meant a significant construction cost savings. As built constructed costs (including the geo-synthetic liner and an additional 15% for design/construction documents & consents) worked out to be approximately $6,500 per $15m^2$ rain garden.

Estimating Construction Costs

In order to estimate a construction cost versus area relationship for rain gardens, Table 2-2 presents a detailed breakdown of the cost items used to estimate the West Harbour Rain Garden Retrofit as a representative example. The West Harbour costs are given for the smaller size of $8m^2$ (for the 10mm design rain event) compared to the larger size of $30m^2$ (for the 28mm rain event) at the same location, along with columns showing the difference in costs as either 'constant' (that is, did not change with the increasing size) or 'variable' (that is, changed with the size of the rain garden). The last columns gives a costing from the Landcare Research COSTnz Model site using the same West Harbour $30m^2$ rain garden size and representative quantities.

Table 2-2 Itemised Rain Garden Costs (D&B Kettle Consulting Ltd 2008 and COSTnz 2012)

Note: Items per West Harbour rain garden 4 at 123 Moire Road, for 8m2 (10mm rain event) and 30m2 (28mm rain event)			West Harbour Rain Garden Retrofit								Landcare Research COSTnz MIDDLE			
			$8m^2$ Rain Garden			$30m^2$ Rain Garden					$30m^2$ Rain Garden			
ITEM	DESCRIPTION	UNIT	QTY	RATE $	VALUE $	QTY	RATE $	VALUE $	Constant	Variable	QTY	Rate	Amount	Constant
1.0	**Preliminary & General**		10%		624	10%		1,102		1,102			1,000	
2.0	**Construction of Pipelines**													
2.1	Installation of 100mm nominal diameter heavy duty perforated pipes in rain garden gravel underdrain	m	5	30	150	16	30	480		480	16	15.45	247	
2.2	Installation of NB100 PE80 SDR11 pipes under the road by trenchless methods, including annulus grouting	m	0	170	0	0	170	0	0					
2.3	Installation of NB100 PVC SN16 pipes by trenching, including PE/PVC special connector	m	5	70	350	5	70	350	350		5	61.5	308	
2.4	Installation of 225mm Class 2 RCRRJ pipes by trenching	m	3	200	600	3	200	600	600		3	130	390	
2.5	17.5MPa concrete bedding to pipelines with gradient 7.5% or steeper	m	0	30	0	0	30	0	0					
2.6	Factory-made PVC SN16 flow spreader	No.	1	250	250	1	250	250	250					
2.7	CCTV and Visual Inspections and Testing	LS.	1	50	50	1	50	50	50					
	Precast wingwalls for flow spreader												850	850
	Locate existing services												1,250	1250
	Break into existing pipe												675	675
3.0	**Construction of Manhole Overflow at Rain Garden**													
3.1	ID1050 manhole with flat grille	No.	1	1,500	1,500	1	1,500	1,500	1,500		1	1950	1,950	1950
4.0	**Connections**								0					
4.1	Kerb outlet and connection to pipeline	No.	1	600	600	1	600	600	600					
4.2	Connection to existing catchpit	No.	0	500	0	0	500	0	0		LS			
4.3	Driveway grate and connection to	No.	0	860	0	0	860	0	0			186	186	186
4.4	RG outlet pipe connection to existing pipeline	No.	1	500	500	1	500	500	500					
5.0	**Rain garden - For two sizes**													
5.1	Excavate and remove surplus	m3	14	30	420	46	30	1,380		1,380	46	26.5	1,219	
5.2	Erosion protection at the inlet and at timber weirs	m2	2	30	60	3	30	90		90	3	126	378	
5.3	Gravel underdrain (thickness 250mm)	m3	2	110	220	7	110	770		770	7	72.9	510	
5.4	Sand bed (thickness 150mm)	m3	1.2	120	144	4.0	120	480		480	4	73.75	295	
5.5	Procure and transport to site, planting soil	m3	8	90	720	30	90	2,700		2,700	30	103.13	3,094	
5.6	Place planting soil (do not compact; loosen any accidental compaction)	m3	8	5	40	30	5	150		150	30	18.5	555	
5.7	Mulch layer (m3 for Costnz)	m2	8	3	24	30	3	90		90	4.5	30.5	137	
5.8	Timber weirs (400mm above ground, 100mm below ground) and anchor poles	m	4	100	400	6	100	600		600		LS	600	
5.9	Planted edge	m	18	12	216	36	12	432		432		LS	432	
5.10	Community education signage	LS.	0	1,000	0	0	1,000	0		0				
	Plants (5 per m2)					30	28	840		840	30	27.5	825	
	Maintenance during establishment (Included in maintenance costs)													
	Sub-total				**6,868**			**12,964**	**3,850**	**9,114**			**14,901**	**4,911**
	Design and Construction documentation			10%	687		10%	1,296		1,296			1,200	
	Uncosted Items and Contingencies			20%	1,374		20%	2,593		2,593		15%	2,235	
	Total (rounded)				**9,000**			**17,000**	**4,000**	**13,000**			18,336	4,911
	Cost per m2				1,125			567					611.21	

Table 2-2 shows the following results:

- The West Harbour 8m^2 rain garden construction cost \$9,000, at \$1,125/m^2.
- The West Harbour 30m^2 rain garden construction cost of \$17,000, at \$600/m^2.
- Of the \$17,000, approximately \$4,000 was a constant fixed cost with \$13,000 of variable cost depending on the size of the rain garden.
- The Landcare Research COSTnz Model gave a similar \$18,300 cost for the 30m^2 rain garden (approximately \$5,000 constant and \$13,300 variable), albeit with slightly different schedule of items.
- The largest items are the constant cost for the manhole overflow (\$1,500 to \$2,000), and the variable costs for excavation and removal of the soil to form the rain garden (\$1,200 to \$1,400 for the 30m^2 size) and replacement with the specified planting media (\$2,700 to \$3,100 for the 30m^2 size).

Using the above indicative relationship between fixed and variable construction costs, an upper bound relationship has been drawn in Figure 2-12 as a ‘red line’ over the plot of construction costs versus water surface area for the range of rain garden examples presented above.

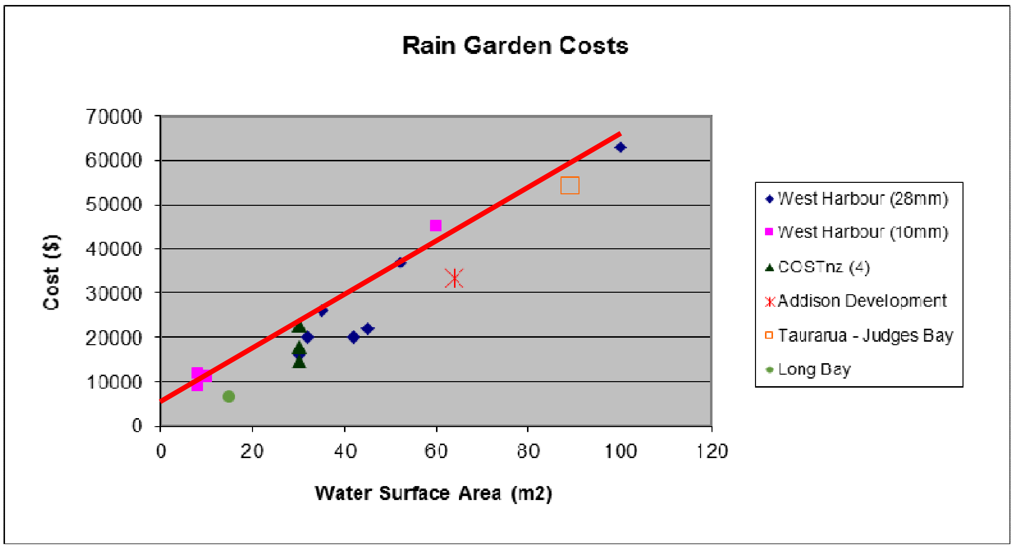


Figure 2-12 Relationship of Rain Garden Cost versus Water Surface Area

The ‘red line’ shows the upper bound ‘high’ cost-surface area relationship with a fixed initial sum of \$5,000 and a variable rate of \$600/m^2.

For a ‘low’ cost relationship, the cost of the Long Bay rain garden has been used. The cost of these rain gardens was approximately \$2,000 plus \$250 to \$350/m^2. The major reduction in the constant cost (reduced from \$5,000 to \$2,000) was the cost of the deleted internal manhole structure. The main reductions in the variable cost component (reduced from \$600/m^2 to \$250 to \$350/m^2) were due to the reduced design quantity and construction unit rates for the excavation and planting/drainage material.

This leads to the following cost estimating formula for standard rain gardens as:

- High Cost = \$5,000 + \$600/m^2 rain garden area
- Low Cost = \$2,000 + \$300/m^2 rain garden area

2.4.2 Household Rain Gardens

Household rain gardens are also likely to vary in cost depending on the size of the catchment, the ease of connecting up to the household piping (e.g. roof downpipes), the reduced need for a concrete manhole structure (replaced with a 100-150mm overflow pipe), the need for detailed design and construction drawings, and whether it is constructed above or below ground (refer Figure 2-13).

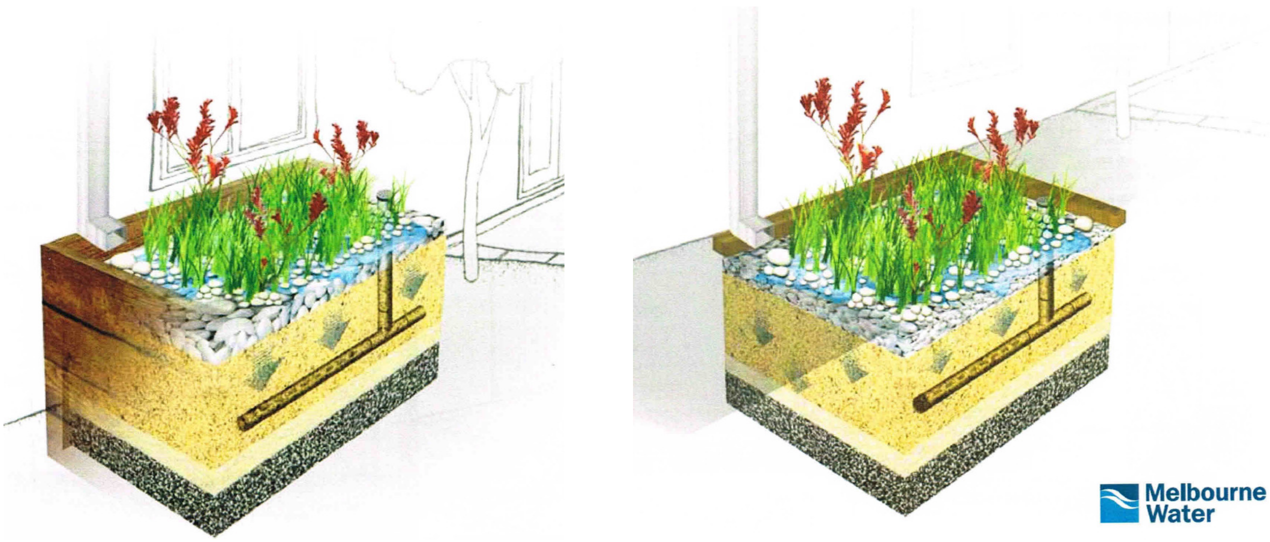


Figure 2-13 Schematic above ground planter box (left) and in ground (right) household rain gardens (Melbourne Water 2013). Image supplied courtesy of Melbourne Water.

Figure 2-13 schematic rain gardens are taken from Melbourne Water's Healthy Waterways 10,000 rain garden project. The project started in 2008, and as of December 2013, has 10,144 registered rain gardens. The project created rain gardens in public spaces such as streets, parks and schools, as well as providing easy step by step instructions for people to design, build and maintain their own household rain gardens.

These Melbourne Water schematic drawings come from a set of instruction sheets which explain in simple language what a rain garden is and how to build and look after it. The instruction sheets are approximately eight A4 pages and give a rain garden sizing chart per area of runoff, a materials list (pipe sizes and construction materials), a plant list, and simple construction drawings giving dimensions and sizes in order for the builder/contractor to construct the rain garden. This simplified standard instruction sheets replace the need for rain garden design and construction drawings to be individually prepared for each house.

With a similar set of instruction sheets being prepared for Auckland, several cost savings could be achieved for household rain gardens over the standard rain garden costs presented above. These savings would be in the following items summarised in Table 2-3.

Table 2-3 Household Rain Garden Savings

Item	Standard Rain Garden (Table 2-2, Landcare Research COSTnz Model)	Household Rain Garden		Explanation
		Cost	Savings	
Precast Wing walls	\$850	\$350	\$500	Use factory-made PVC flow spreader.
Manhole	\$1,950	\$450	\$1,500	1050 concrete manhole not required. Use 100/150mm PVC.
Design and Construction docs.	10%		10% of variable cost	The use of standard instruction sheets reduces the need for specific design and construction drawings to be individually prepared for each house.

From Table 2-3, the first two items (precast wing walls and the manhole) are constant savings per rain garden and the design and construction documents cost is calculated as a percentage of the overall cost. The wing walls and manhole costs are only included in the 'high' range standard rain garden costs, therefore, for the household rain garden cost, only reduce the constant high range cost by \$2,000 of savings. For the 10% for design and construction documentation, only apply these savings to the 'variable' cost and not to the 'constant' cost. This reduces the 'high' range variable cost from \$600 to \$540/m^2 of surface area, and the 'low' range cost from \$300 to \$270/m^2. All other costs are kept the same as for the standard rain garden to maintain the similar 'low – high' differential costs.

This leads to the following cost estimating formula for household rain gardens as:

- High Cost = \$3,000 + \$540/m^2 rain garden area
- Low Cost = \$2,000 + \$270/m^2 rain garden area

2.4.3 Tree Pits

While not fully costed, tree pits may be a good alternative to rain gardens where space is limited. Tree pits can be used for the location of trees in confined spaces where structural support is required for adjacent paved surfaces. Tree pits can be either a constructed concrete box or a geogrid structural soil cell. One critical aspect with tree pits is the ability to provide enough soil mix around the tree to allow for expansion of the tree roots. International literature and experience of Auckland Council arborists indicate a minimum of 10 to 15m^3 of planting soil is required per tree to support a healthy street tree.

Constructed Concrete Boxes

Constructed concrete box tree pits can be square or round, include a bypass overflow chamber and need to have sufficient holes/slots in the upper parts of the concrete walls to allow roots to grow out from inside the tree pit to the surrounding soils. Note that these concrete box tree pits can be constructed with a concrete bottom and can act as an impermeable lining which means they can be installed in geotechnically sensitive areas.

The cost of these tree pits will vary depending on supplier and quantity. As of December 2012 these are only manufactured to order, but as demand increases the supplier could make a mould and hence reduce their unit cost. Indicative supply costs from local supplier are $7,500 + GST for a one off, which could be reduced to $5,500 - $6,000 + GST each for a production run after the construction of a mould. If 30% is added for installation, the construction cost is approximately:

One off - 2.5m x 2.5m (6.25m^2) Tree Pit = $10,000 each, at $1,600/m^2

Production run - 2.5m x 2.5m (6.25m^2) Tree Pits = $7,500 each, at $1,200/m^2

Geogrid Structural Soil Cell

This type of tree pit comprises a series of geogrid structural cells filled with uncompacted free draining soil to allow the roots to spread away from the tree. The geogrid cells provide the structural support for the pavement surface and traffic loads.

Indicative pricing from Auckland Council Arborist for the excavation, disposal of excavated soil, and replacement with the geogrid cells (on 200mm of AP25 gravel basecourse) filled with free draining planting mix is in the order of $850 to $1,000 per m^3.

2.4.4 Conventional Landscaping Costs

For bio-retention devices it is appropriate to also give conventional landscaping costs of a similar looking landscaped planted strip, without a stormwater management function.
The cost of a similar landscaped planted strip is estimated at:

- $30/m^2 for 300mm of good quality topsoil
- $17/m^2 for planting and mulch (Source: WT Partnership 2013)
- Kerbing (including subsoil drain) at $90/m (Source: WT Partnership 2013), if typical 2.5m wide planted strip, then use 1m of kerb per 2.5m^2 of planting (assume cost of kerb on one side, other side foot path), which is $36/m^2
- Giving Total of $30 + $17 + $36 = $83/m^2, say $85/m^2.

Assume the cost of conventional grass planting (e.g. road verge) is 300mm of good quality topsoil (at $30/m^2) plus grass at $0.50/m^2 = $30.50/m^2, say $30/m^2.

2.5 Maintenance Costs

Estimated maintenance costs have been gathered from a range of sources, including:

- Landcare Research COSTnz Model. COSTnz data is based on design, construction and maintenance techniques at the time of model development (2006).
- Local maintenance contractor.
- Auckland Council maintenance personnel.
- Melbourne and South East Queensland studies.

2.5.1 Landcare Research COSTnz Model

The Landcare Research COSTnz Model gives the following maintenance items for a typical 30m^2 rain garden.

On-going maintenance:

- Routine general maintenance (removing debris, cleaning inlets and outlets, maintaining vegetation) 12 per year at \$800 (low - \$2.16/m^2) to \$1,800 (high - \$5/m^2).
- Inspections 1 per year at \$100 (low) to \$260 (high).
- Minor repairs 1 per year at \$80 (low) to \$100 (high).
- Initial after care of plants for first 3 years at \$120 per year (low - \$1/m^2, 4 times per year) to \$350 per year (high - \$2.90/m^2, 4 times per year).
- TOTAL annual for first three years = \$1,100 (low) to \$2,500 (high) per year.
- TOTAL annual subsequent years = \$980 (low) to \$2,160 (high) per year.

Corrective maintenance:

- Removal and disposal of sediments (including replacement of new media) every 25 years at \$13,500 (low - \$450/m^3) to \$58,000 (high - \$1,920/m^3).
- Replanting every 25 years at \$900 (low - \$30/m^2) to \$1,400 (high - \$47.50/m^2).
- Replacement of parts every 10 years at \$1,000 (low) to \$3,250 (high) – this is likely to occur every 25-years during replanting.
- TOTAL of above three is \$15,400 to \$62,650 every 25-years.

For household rain gardens the maintenance costs would be less as most of the routine general maintenance would be carried out by the owner as part of their regular garden/lawn care. The corrective maintenance media replacement is also probably unnecessary due to the low level of contaminants. Therefore, for estimating purposes assume the following:

- For first three years, replacement of any failed plants, at five plants per square metre @ \$2 per plant = \$10/m^2. For 10% to 20% replacement of a 30m^2 rain garden, is 3 to 6m^2 at \$10/m^2 = \$30 to \$60, say \$1 to \$2/m^2 of rain garden area.
- Allow one council inspection per year for first three years, then once every three years thereafter, at \$100 per inspection.
- Allowance for minor repairs and adding more mulch at \$250 every 5 to 10 years.

2.5.2 Maintenance Contractor

For comparison, estimated maintenance costs of rain gardens were obtained from a local Auckland maintenance contractor. Their rates were similar to the COSTnz rates for the first three years (and similar corrective maintenance), but approximately one quarter of the COSTnz for the annual subsequent years. The suggested maintenance costs were:

Routine Maintenance:

- Routine general maintenance (removing debris, cleaning inlets and outlets, maintaining vegetation and mulch) 2 to 4 per year at $125/visit = $250 (low) to $500 (high).
- Initial after care of plants for first 3 years at 6 visits per year @ $150 per visit = $900.
- TOTAL annual first three years = $1,200, average of $1025 (low) to $1,400 (high) per year.
- TOTAL annual subsequent years = $375, average of $250 (low) to $500 (high) per year.

Corrective maintenance:

- Minor repairs at $250 every 3 years.
- From their one example rain garden recently replaced, estimate for removal and disposal of sediments, new media and also the replanting could range from $500 to $1,500/m^3, that is, $15,000 to $45,000 for a 30m^2 rain garden every 25 years.

2.5.3 Auckland Council

Maintenance costs were also obtained from Auckland Council Infrastructure & Environmental Services. Maintenance is carried out monthly for raking surface, litter and weeds removal. Costs are estimated at $67.56 per month per garden, equating to $810 per year per garden. Note that this is per garden, not per m^2.

Another source for estimating the corrective maintenance cost is by using the desilting and sediment disposal costs from pond projects carried out in Rodney and North Shore in 2012/13 financial year (refer Section 7.6). An indicative desilting and disposal to landfill cost of these projects is around $250/m^3. For a 30m^2 rain garden, 1m depth, equates to $7,500. Costs to rebuild (using Landcare Research COSTnz Model 'middle' unit costs from Table 2-2 presented below:

- Replacement parts/pipes/other - $1,000
- Erosion protection - $400
- Sand bed - $300
- Planting media to site - $3,000
- Place planting media - $600
- Mulch layer - $150
- Replanting - $1,000
- Contingency 15%
- Rebuild TOTAL = $7,500

Giving a total corrective maintenance cost of $7,500 (removal and disposal) + $7,500 (rebuild) = $15,000. This being at the low end of the COSTnz corrective maintenance cost range given above.

2.5.4 Melbourne

Another source of maintenance costs is from Melbourne, Australia, from a study of 22 rain garden sites in 2006 (Land and Water Constructions 2007). The study developed a typical low and high range for yearly maintenance costs, refer Table 2-4 (multiplied by 1.2 to convert AUS$ to NZ$).

Table 2-4 Annual Maintenance Costs, Melbourne (adapted from Land and Water Constructions 2007)

Activity	Per Square Metre		Per $30m^2$ Rain Garden	
	Low	High	Low	High
Aesthetics	$5.80	$8.60	$175	$260
Vegetation	$3.60	$5.00	$110	$150
Inspections	$1.15	$2.30	$35	$70
TOTAL (NZ$)	**$10.55**	**$15.90**	**$320**	**$480**

Table 2-4 indicates a range of $320 to $480 maintenance costs per year for a $30m^2$ rain garden. The report commented that much of the maintenance cost is associated with annual inspections and litter pick up. The report recommended that if reductions in maintenance inputs are desired that savings be made in these areas, rather than weed control and replanting.

2.5.5 South East Queensland

Another Australian example is that presented in the South East Queensland 'Business Case' (Water by Design 2010) with an annual maintenance cost of NZ$18/$m^2$/year ($540 for a $30m^2$ rain garden) for the first 2 years, with subsequent on-going annual maintenance of NZ $6/$m^2$/year ($180 for a $30m^2$ rain garden). It is noted that these maintenance costs are significantly lower than those from the Landcare Research COSTnz Model and the maintenance contractor (refer summary Table 2-5 below), which could be a reflection of greater contractor familiarity and price competition from a more widespread use of rain gardens.

South East Queensland also give on-going annual maintenance costs for standard landscaping at NZ $3/$m^2$/year, (NZ $90/year for a $30m^2$ rain garden) which is half of that for the rain garden.

2.5.6 Recommended Rain Garden and Landscape Maintenance Costs

A summary of the above maintenance costs and the recommended range to be used for cost estimating purposes is presented below in Table 2-5 for a representative on-site $30m^2$ rain garden. Further explanation about the values used for the recommended unit costs is presented after the table.

The choice of the $30m^2$ example rain garden was chosen as representative for typical on-site devices. Allowance for variation in maintenance costs per rain garden size and location have been accommodated by using a fixed sum per household, for the smaller individual household rain gardens, and a variable rate for multiple or larger rain gardens in parking areas and roads.

Table 2-5 Rain Garden Maintenance Costs

Maintenance Costs (for a 'standard' 30m² rain garden)	COSTnz	Local Maintenance Contractor	South East Queensland	Recommended Unit Costs
Routine annual maintenance (first 3 years)	\$1,100 to \$2,500	\$1,025 to \$1,400	\$540	Range of \$1,000 to \$1,500 (\$35 - \$50/m²)
On-going annual maintenance	\$980 to \$2,160	\$250 to \$500	\$180	Range of \$500 to \$800 (\$17 - \$27/m²)
Corrective maintenance (every 25 years)	\$15,400 to \$62,650	\$15,000 to \$45,000	40% of construction cost = approx. \$5,000	Range of \$15,000 to \$25,000 (\$500-\$850/m²)
Note: Using a removal and disposal cost of \$250/m³ (from Auckland Council pond desilting project costs) and a rebuild cost based on COSTnz unit rates gives a total 25-year corrective maintenance cost of \$15,000.				
On-going annual maintenance from other sources				
Auckland Council, Infrastructure & Environmental Services	\$67.56 per month per garden		Equates to \$810 per year per garden	
Melbourne study (NZ\$)	\$10.55 to \$15.90 per year per m² of garden		Equates to \$320 to \$480 per year per 30m² garden	
<u>Household rain garden</u> maintenance (assuming most of routine general maintenance carried out by owner as part of regular garden/lawn care and corrective maintenance of replacing media not required due to low contaminant levels)				
First three years replacement of failed plants	10% to 20% replacement plants		\$30 to \$60 per garden (\$1 to \$2/m²)	
Council inspections	One per year for first three years, then once every three years thereafter.		\$100 per year for first 3 years, then \$100 every 3 years thereafter	
Minor repairs and adding mulch	Every 5 to 10 years		\$250 every 5 to 10 years	

Explanations for the choice of values used for maintenance costs

For routine annual maintenance for the first 3 years, the lower range of \$1,000 per year is from the lower range of the COSTnz (\$1,100) and local maintenance contractor (\$1,025). The higher range of \$1,500 is from the low/mid-range of COSTnz and slightly higher than the local maintenance contractor upper limit. Note that the South-East Queensland cost of \$540 is significantly lower.

For on-going annual maintenance (after the first 3-years), the range of \$500 to \$800 is at the higher end of the local maintenance contractor costs, but below the COSTnz costs. The upper \$800 is similar to the \$810 estimate received from Auckland Council, Infrastructure & Environment Services. Both the Queensland (\$180) and Melbourne (\$320 to \$480) costs are less and could represent a more probable future price with efficiencies of scale and greater familiarisation over time.

Corrective maintenance is the greatest unknown because existing rain gardens have not been in long enough to require this work yet. The lower range of $15,000 is based on the estimated price using pond desilting costs and estimated unit rates from COSTnz to rebuild. It is also similar to the low range from COSTnz ($15,400) and local maintenance contractor ($15,000). The upper range of $25,000 is adding on an additional $10,000 for uncertainties and variations. This upper range is still only approximately half the upper COSTnz and local maintenance contractor ranges, but considered appropriate given the greater confidence of the estimated $15,000 using actual pond desilting costs and unit rates to rebuild. This corrective maintenance rebuild is assumed to occur every 25 years. After each 25 year rebuild an additional three years of increased maintenance for after care of plants is required.

For household rain gardens use estimated cost to replace failed plants in first three years and then the cost of minor repairs that could occur every 5 to 10 years. Allow for yearly council inspections for first three years, and then every three years thereafter.

For annual maintenance of conventional landscaping use a ‘high’ of $3/m^2/year for landscaped garden bed and $1/m^2/year for landscape turf (grass) from South East Queensland. Reduce the values by 30% to get ‘low’ values of $2/m^2/year for landscaped garden beds and $0.70/m^2/year for landscape turf/grass.

2.6 Total Present Costs

The following tables (Table 2-6 and Table 2-7) summarise the ‘low’ and ‘high’ range of construction, maintenance and total present costs for rain gardens and conventional landscaped areas. Total present costs have been calculated for a 60-year appraisal period using a real discount rate of 4%.

Total present costs have been estimated using the recommended construction and maintenance costs from the above sections.

The values in the following tables have been used as the unit rates to estimate the ‘scenario’ costs in the main report.

Table 2-6 Recommended Conventional Landscape Unit Costs

LANDSCAPING	Low	High
Conventional Landscaped Planted Strip - Vegetated		
Construction (per m2)	$ 60	$ 85
Maintenance - annual (per m2)	$ 2	$ 3
TOTAL PRESENT COST (per m2)	$ 107	$ 153
Conventional Landscaped Turf (grass)		
Construction (per m2)	$ 20	$ 30
Maintenance - annual (per m2)	$ 0.7	$ 1.0
TOTAL PRESENT COST (per m2)	$ 36	$ 53

Table 2-7 Recommended Bioretention Unit Costs

BIORETENTION	Low	High
Standard Rain Garden		
Construction		
- Fixed	$ 2,000	$ 5,000
- Variable (per m^2)	$ 300	$ 600
Maintenance		
Average Annualised (per m^2)	$ 36	$ 58
TOTAL PRESENT COST		
- Capital Costs	Equal to Construction Cost	
- Maintenance Costs (per m^2)	$ 709	$ 1,132.10
Individual Household Rain Garden - reduced routine maintenance $$ (per house) and no corrective maintenance		
Construction		
- Fixed	$ 2,000	$ 3,000
- Variable (per m^2)	$ 270	$ 540
Maintenance		
Average Annualised (per house)	$ 63	$ 90
TOTAL PRESENT COST		
- Capital Costs	Equal to Construction Cost	
- Maintenance Costs (per house)	$ 1,500	$ 2,100
Communal Household Rain Garden - with routine maintenance contract (per m^2) and no corrective maintenance		
Construction		
- Fixed	$ 2,000	$ 5,000
- Variable (per m^2)	$ 300	$ 600
Maintenance		
Average Annualised (per m2)	$ 18	$ 28
TOTAL PRESENT COST		
- Capital Costs	Equal to Construction Cost	
- Maintenance Costs (per m2)	$ 435	$ 675

3.0 Porous Paving

3.1 Introduction

Porous paving consists of a permeable wearing surface that is bedded in sand/fine gravel, overlying a gravel basecourse to enable rainwater infiltration to an underdrain and/or ground infiltration (refer Figure 3-1).

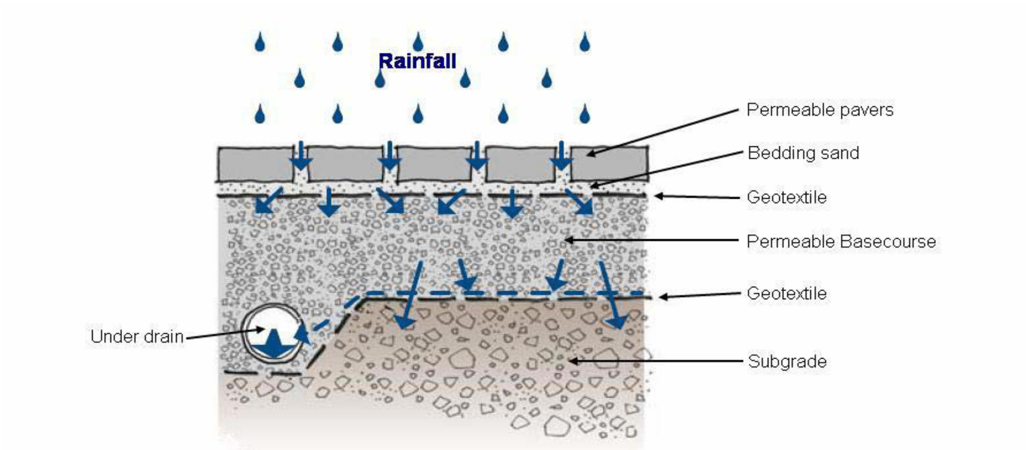


Figure 3-1 Typical Layers in a Porous Paving System (Auckland Council 2011)

A number of different surfaces can be used for porous pavements, including porous concrete pavers, porous concrete or asphalt, or grass pavers/gobi blocks. Costs are given below for porous concrete pavers (water infiltration through the porous nature of the paver or through the 6mm sand filled gaps between standard impermeable blocks). Cost has not been included for porous concrete/asphalt (not used widely in the Auckland area) or grass pavers (do not provide the required infiltration rate).

Porous paving allows runoff to infiltrate into the underlying basecourse where it is temporarily stored and slowly released either into the underlying basecourse or subgrade. This provides stormwater attenuation of the peak flows, volume reduction through infiltration and wetting/drying of the filtration media and water quality treatment due to settling, filtration, adsorption and microbiological action in the bedding sand and basecourse.

3.2 Variability in Calculating Costs

Porous paving costs can vary due to:

- Type of paving system – porous concrete pavers, porous concrete/asphalt, or grass pavers/gobi blocks. Only the costs for the porous concrete blocks are presented here.
- Size of device – construction area influences the construction efficiencies with mob/demob and operation/size of the construction equipment. The larger the site, the more the cost efficiencies.
- For paving, the condition of the subgrade can also make a big difference to the overall cost. For example, a soft subgrade may require over-excavation and backfill with a greater

thicknesses of the basecourse metals. Because this report largely focuses on comparative costs of different options, the subgrade condition is not that critical, as it is likely to have a similar impact on all of the options considered.

- Use of paving system – different structural thicknesses of the paving system are required depending on the use of the paving system for a footpath (e.g. 100mm basecourse depth), driveway (e.g. 150mm basecourse depth) or parking area (350mm basecourse depth). Porous paving is not recommended for medium to heavy trafficked areas.
- Need for an impermeable lining – in areas of slope instability an impermeable lining is required as infiltrating water into the subsoils can adversely affect slope stability.
- Structural elements – for example, all paving systems require some form of lateral restraint, such as a concrete edge beam around the perimeter of the paved area.

3.3 Costing Data Sources

Only one porous paving costing source was available:

- Itemised breakdown of construction cost schedule of quantities for Tamahere Retirement Village was obtained from a porous paving supplier.

The Landcare Research COSTnz Model does not include porous paving.

Costing sources for the conventional pavements are:

- Personal communication with Auckland Transport asset management staff.
- Rawlinsons New Zealand Construction Handbook, 2010.
- WT Partnership Infrastructure (2013). Drury South Business Park Peer Review of the Beca Estimate for the Public Works, for Auckland Council.

3.4 Construction Costs

3.4.1 Parking Areas

For porous paving parking areas an assumed basecourse thickness of 350mm has been used. See Table 3-1 for itemised costs for an example 1,000m^2 of paving area and Figure 3-2 for photos of porous paving parking areas in the Auckland area.

Table 3-1 Itemised Porous Paving Costs for Parking Area (porous paving supplier, reproduced with permission)

Product	Thickness	Area M2	Qty	Units	Rate	Rate	Cost
Permeable paver Flowpave 80mm	1	1000	1000	m2	$45.00	m2	$45,000.00
Bedding							
WAPP 7 chip 20mm bedding +10mm joints	0.03	1000	30	m3	$55.00	ton	$2,310.00
Sub - base							
WAPP12 (assume 350mm thick)	0.35	1000	350	m3	$40.70	ton	$19,943.00
Filter cloth top and bottom + 2 sides class D	1	1000	2037.9	m2	$2.70	m2	$5,502.38
Bi axial geogrid 30/30	1	1000	1000	m2	$4.00	m2	$4,000.00
Sub surface drainage	1		100	m	$30.00	m	$3,000.00
Haunching	1		150	m	$6.00	m	$900.00
					Material cost	**Total**	**$80,655.38**
					Material cost	**Total m2**	**$80.66**
Installation costs							
Labour	**Thickness**	**Area M2**	**Qty**	**Units**	**Rate**	**Units**	**Cost**
Permeable paver Flowpave 80mm	1	1000	1000	m2	$21.00	m2	$21,000.00
Bedding							
WAPP 7 chip 20mm bedding +10mm joints	1	1000	1000	m2	$5.00	m2	$5,000.00
Sub - base							
Basecourse at 350mm	0.35	1000	350	m3	$50.00	m3	$17,500.00
Filter cloth top	1	1000	1000	m2	$1.00	m2	$1,000.00
Bi axial geogrid 30/30	1	0	0	m2	$2.00	m2	$0.00
Sub surface drainage	0	0	100	m	$5.00	m	$500.00
Haunching	0	0	150	m	$12.00	m	$1,800.00
					Install cost	**Total**	**$46,800.00**
					Install cost	**Total m2**	**$46.80**
TOTAL RATE	**$127.46**						

For estimated costings use $128/m^2 plus 15% design, construction drawings and contingencies for $150/m^2 (with 350mm basecourse).

For conventional costs for parking areas assume 35mm AC with 150mm M4 basecourse over 200mm GAP65 sub base for similar durability and finish to that of the pavers:

- 35mm AC at $30/m^2.
- 150mm M4 basecourse at $70/m^3 supply plus $50/m^3 install for $120/m^3, giving $18/m^2.
- 200mm GAP65 sub base at $60/m^3 supply plus $50/m^3 install for $110/m^3, giving $22/m^2.
- Total of $30 plus $18 plus $22 = $70/m^2 plus 15% for $80/m^2.

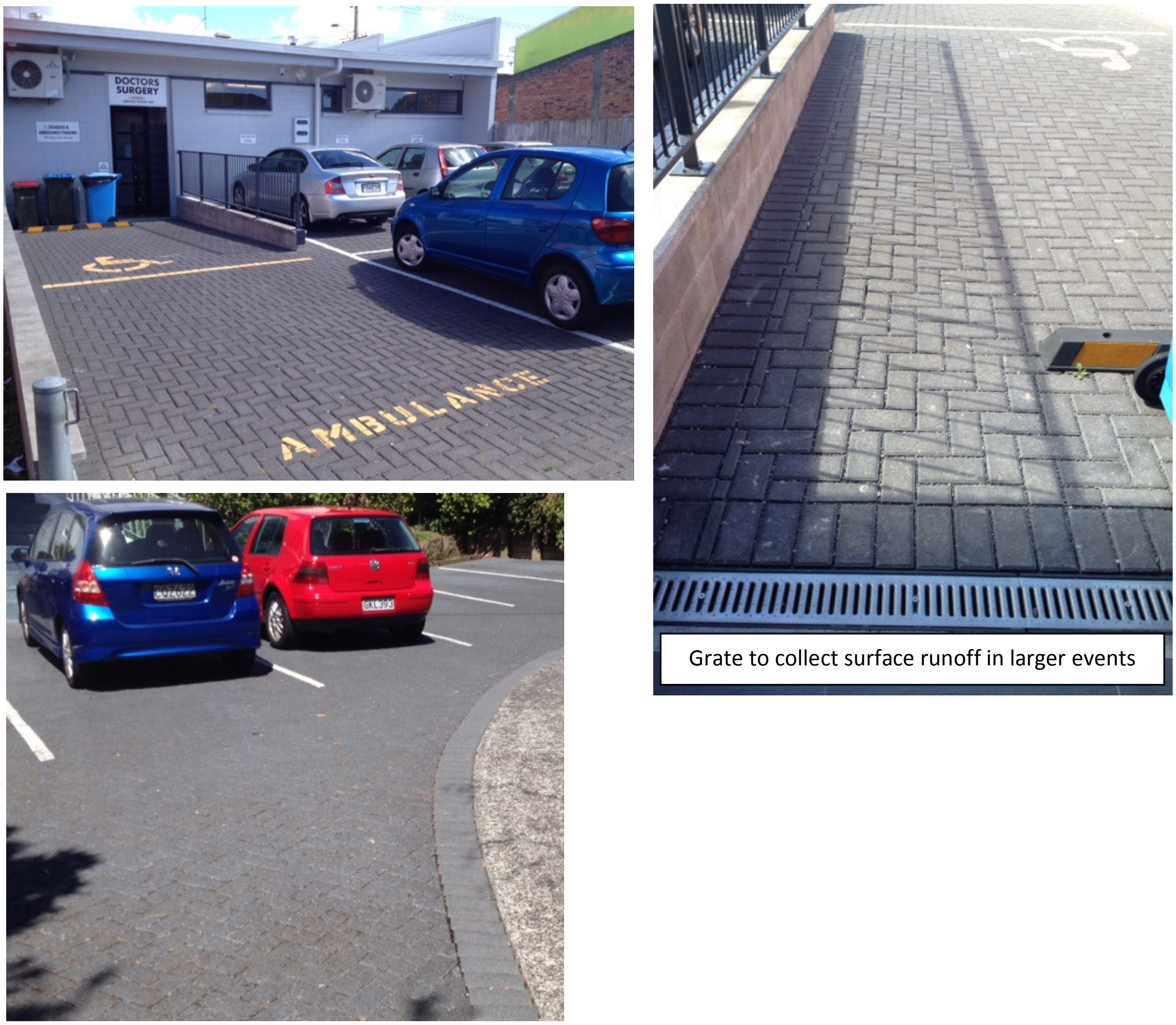


Figure 3-2 Photos of Porous Paving Car Parking Areas – Auckland (D&B Kettle Consulting Ltd 2013b)

3.4.2 Driveways

For paving block driveways an assumed basecourse depth of 150mm has been used. See Table 3-2 for itemised costs for an example 45m^2 of paving area and Figure 3-3 for photos of porous paving driveways in the Auckland area.

Table 3-2 Itemised Porous Paving Costs for Driveway (porous paving supplier, reproduced with permission)

Materials Cost									
Product	**Thickness**	**Area M2**	**Qty**	**Units**	**Rate**	**Units**	**Cost**		**per m2**
Permeable paver Flowpave 80mm	1	45	45	m2	$45.00	m2	$2,025.00		$45.00
Bedding									
WAPP 7 chip 20mm bedding +10mm joints	0.03	45	1.5	m3	$118.14	m3	$177.21		$3.94
Base									
150mm x12mm agg	0.15	45	6.75	m3	$70.00	m3	$472.50		$10.50
Filter cloth top	1	45	50	m2	$2.70	m2	$135.00		$3.00
Bi axial geogrid 30/30 (remove)	0	45	0	m2	$4.00	m2	$0.00		$0.00
Sub surface drainage	0	0	10	m	$30.15	m	$301.50		$6.70
Haunching	0	0	32	m	$6.00	m	$192.00		$4.27
					Material cost	**Subtotal**	**$3,303.21**		
					Material cost	**Total m2**	**$73.40**		$73.40
Installation costs									
Labour	**Thickness**	**Area M2**	**Qty**	**Units**	**Rate**	**Units**	**Cost**		
Permeable paver Flowpave 80mm	1	45	45	m2	$21.00	m2	$945.00		$21.00
Bedding									
WAPP 7 chip 20mm bedding +10mm joints	1	45	45	m2	$5.00	m2	$225.00		$5.00
Sub - base									
Basecourse at 150mm	0.15	45	6.75	m3	$50.00	m3			$7.50
							$337.50		
Filter cloth top	1	45	50	m2	$1.00	m2			$1.00
							$50.00		
Bi axial geogrid 30/30	0	0	0	m2	$2.00	m2			
							$0.00		
Sub surface drainage	0	0	10	m	$5.00	m	$50.00		$1.11
Haunching	0	0	28	m	$12.00	m	$336.00		$7.47
					Install cost	**Subtotal**	**$1,943.50**		
					Install Cost	**Total m2**	**$43.19**		43.07778
Total Rate	**$116.59**	**/m2**							

For estimated costings use $117/m^2 plus 15% design, construction drawings and contingencies for $135/m^2.

Conventional costs for concrete driveways assume 110mm thick 20MPa 19mm concrete with one layer of 665 mesh (including formwork to edges) with 100mm basecourse.

- 110mm thick 20MPa 19mm concrete with mesh at $80/m^2.
- 100mm M4 basecourse at $70/m^3 supply plus $50/m^3 install for $120/m^3, giving $12/m^2.
- Total of $80 plus $12 = $92/m^2 plus 15% = $105/m^2.

Figure 3-3 Photos of Porous Paving Driveways – Auckland (D&B Kettle Consulting Ltd 2013b)

3.5 Maintenance Costs

3.5.1 Local Data

Porous paving maintenance items include (porous paving supplier, reproduced with permission):

- For small 'in-lot' installations, (such as driveways),
  - End of first year and every ten years - Top up of joint chip between pavers at \$5.50/m^2 (average thickness of 5mm @\$100/m^3 = \$0.50/m^2, plus installation @ \$5/m^2, plus joint chip stabilisation additive @ \$5/m^2,for a total of \$10.50/m^2).
  - No cost of general inspection carried out by owner, but allow \$100 for council inspections every year for first three years, then once every three years thereafter.
  - Every year - General cleaning/weed control @ \$1/m^2 to cover possible incidentals for cleaning.
  - Assume no corrective maintenance to uplift and dispose of sand bedding and geotextile due to low contamination levels.
- For larger installations, (such as parking lots of 1,000m^2)
  - End of first year and every five years alternating with 10-year corrective maintenance - Top up of joint chip between pavers at \$5.50/m^2 (average thickness of 5mm @\$100/m^3 = \$0.50/m^2, plus installation @ \$5/m^2, plus joint chip stabilisation additive @ \$5/m^2 for a total of \$10.50/m^2)
  - Every year - General inspection, 2 @ \$140 per year = \$280 per year per 1,000m^2.
  - Every year - General cleaning/weed control @ \$1.50/m^2 per year (including vacuum sweeping at \$0.10/m^2).
  - Every ten years - Corrective maintenance, it may be necessary to uplift the pavers and replace the sand bedding and its geotextile @\$42/m^2. All material sucked and removed from porous paving must be disposed of to landfill. (Based on uplifting of pavers/sand bedding/geotextile and disposal of bedding/geotextile to landfill @ \$10/m^2 and relay pavers with new sand bedding and geotextile @ \$32/m^2), and joint chip stabilisation @ \$5/m^2).
  - Every 20 years allow for replacement with new pavers. Total cost includes uplifting pavers and replacement of sand bedding and geotextile @ \$47/m^2, plus cost of new pavers @ \$45/m^2 and \$20/m^2 for disposal of old pavers, for total of \$112/m^2.

For conventional asphalt areas, on-going maintenance has been estimated for 1,000m^2 parking area, and 40m lengths of '5,000 vpd' road and a secondary arterial (Bencich 2013 and McSpadden 2013), refer Table 3-3.

Table 3-3 Conventional Parking and Road Maintenance Costs (Bencich, McSpadden 2013)

Frequency	Item	1,000m² Parking		5,000 vpd Road (40m length, 736m²)		Secondary Arterial (40m length, 1,108m²)	
		Description	**Cost**	**Description**	**Cost**	**Description**	**Cost**
Yearly 1 to 5	Maintenance Inspec.	2 x $140	$ 280	4 x $140	$ 560	12 x $140	$ 1,680
	Surface sweeping	6 x $0.10/m²	$ 600	same rate	$ 442	same rate	$ 665
	Weed control	if necessary	$ 100	3 x parking	$ 300	3 x parking	$ 300
	TOTAL YEARLY		$ 980		$ 1,302		$ 2,645
	TOTAL YEARLY per m²		**$ 1.0**		**$ 1.8**		**$ 2.4**
Yearly 6 to 10	As above plus						
	Lichen/moss control	1 per year	$ 450	N/A		N/A	
	Surface crack sealing	50lm per yr	$ 325	same rate	$ 239	same rate	$ 360
	Pot holes	15m² per yr	$ 1,125	same rate	$ 828	same rate	$ 1,247
	Subtotal		$ 1,900		$ 1,067		$ 1,607
	Subtotal per m²		$ 1.9		$ 1.5		$ 1.5
	TOTAL YEARLY per m²		**$ 3**		**$ 3.2**		**$ 3.8**
Year 10 resurface		**N/A**		**N/A**		**40mm AC mill & place @ $35/m²**	**$ 35**
Yearly 11 to 19	As above yearly plus						
	Larger failures	20m² per yr	$ 5,000	20m² per yr	$ 3,680	40m² per yr	$ 11,080
	Subtotal per m²		$ 5		$ 5		$ 10.00
	TOTAL YEARLY per m²		**$ 7.9**		**$ 8.2**		**$ 14**
Year 20	**Rehab**	**Full rehab @ $100/m²**	**$ 125**	**Additional repairs @ $10/m2 plus 25mm AC mill & place @ $25/m²**	**$ 35**	**Additional repairs @ $15/m2 plus 40mm AC mill & place @ $35/m²**	**$ 50**
Yearly 21 to 25		as for yr 1-5	$ 1.0	As for yr 6-10	$ 3.2	As for yr 6-10	$ 3.8
Yearly 26 to 29		as for yr 6-10	$ 3.0	As for yr 11-19	$ 8.2	As for yr 11-19	$ 14.0
Year 30		**as for yr 10**	**$ 3.0**	**Full rehab @ $100/m²**	**$ 100**	**Full rehab @ $150/m²**	**$ 150**
After Year 30		**as for yr 11**		**as for yr 1**		**as for yr 1**	

3.5.2 International

As maintenance of porous paving is still relatively new in New Zealand, maintenance costs in other countries are given below in Table 3-4 for comparison (Royal HaskoningDHV 2012).

Table 3-4 Porous Paving Maintenance Costs

Activity	Unit	(UKWIR 2005)		NZ Larger Installations (from above)	
		Cost (NZ$)(1)	Freq.	Cost (NZ$)	Freq.
Inspection, reporting and information management	Site	$70	1 month to 1 year	$200 per 1,000m^2	yearly
Litter and minor debris removal	m^2	$0.05	1 month to 5 years	$1.50	yearly
Sweeping	m^2	$0.07	4 months to 1 year		
Remove block pavers, remove and dispose 5mm single aggregate	m^2	$32	25 to 45 years	$10	10 years
Install replacement geotextile, install new 5mm aggregate bedding layer and reinstate block (including $5/m^2 for joint chip stabilisation additive for NZ installations).	m^2	$22	25 to 45 years	$37	10 years

(1) Using conversion rate of 1UK£ = 1.8NZ$

Royal HaskoningDHV (2012) also cited other sources of regular maintenance costs from:

- Environment Agency (2007): £0.40/m^2, equal to NZ$0.72/m^2.
- HR Wallingford (2004): £0.5 to £1.0/m^3 stored volume, equal to approx. NZ$0.10 to NZ$0.20/m^2 (based on 30% voids ratio)
- SuDS Unit Cost Database: £0.6 to £1.3/m^3 stored volume, equal to approx. NZ$0.12 to NZ$0.23/m^2 (based on 30% voids ratio).

It can be seen that these UK regular annual maintenance costs of between NZ$0.10 to NZ$0.20/m^2 are similar to the standard AC paving surface sweeping of $0.10 per m^2 at six per year (see costs from Bencich above).

For driveways the maintenance costs are reduced due to the low traffic loads and level of contaminants (assume no corrective maintenance to uplift, dispose and replace layers):

<u>Porous Paving</u>

- Top up joint chip @ $5.50/m^2 plus joint chip stabilisation additive $5/m^2, for a total of $10.50 at end of year 1 and every 10 years.
- General inspection by landowner (assumed no monetary charge as will be carried out by landowner as part of general yard maintenance), but allow $100 council inspection each year for first three years, then once every three years thereafter.
- Cleaning/weed control @ $1.00/m^2 every year.

Concrete Paving

- Assume no ongoing maintenance cost for concrete driveway as only owner infrequent cleaning is necessary.

3.6 Total Present Costs

The following tables (Table 3-5 to Table 3-8) summarise the 'low' and 'high' range of construction, maintenance and total present costs for porous paving and conventional surfaces. The low and high ranges were estimated from using the above costs as the 'median' cost and then varying them by +/- a percentage. For porous paving costs, with greater uncertainty, a range of +/- 20% has been used, with a smaller percentage range of +15% and -10% for the conventional surfaces with more certainty of costing unit rates. Total present costs have been calculated for a 60-year appraisal period using a real discount rate of 4%.

Total present costs have been estimated using the recommended construction and maintenance costs from the above two sections.

The values in the following tables have been used as the unit rates to estimate the 'scenario' costs in the main report.

Table 3-5 Recommended Porous Paving Unit Costs

POROUS PAVING	Low (-20%)	High (+20%)	Median
Porous Parking Areas			
Construction (per m^2)	$ 120	$ 180	$ 150
Maintenance			
Average Annualised (per m^2)	$ 8.8	$ 13.2	$ 11.0
TOTAL PRESENT COST (per m2)	$ 282	$ 423	$ 353
Porous Household Driveway			
Construction (per m^2)	$ 108	$ 162	$ 135
Maintenance			
Average Annualised (per m^2)	$ 2.50	$ 3.74	$ 3.12
TOTAL PRESENT COST (per m2)	$ 169	$ 253	$ 211

Table 3-6 Recommended Conventional Surfaces Unit Rates

CONVENTIONAL SURFACES	Low (-10%)	High (+15%)	Median
Asphalt Parking Areas (350mm base)			
Construction (per m^2)	$ 72	$ 92	$ 80
Maintenance			
Average Annualised (per m^2)	$ 8.6	$ 11.0	$ 9.6
TOTAL PRESENT COST (per m2)	$ 224	$ 286	$ 249
Local Road (400mm base)			
Construction (per m^2)	$ 81	$ 104	$ 90
Maintenance			
Average Annualised (per m^2)	$ 8.5	$ 10.8	$ 9.4
TOTAL PRESENT COST (per m2)	$ 229	$ 292	$ 254
Arterial Road (600mm base)			
Construction (per m^2)	$ 108	$ 138	$ 120
Maintenance			
Average Annualised (per m^2)	$ 13.9	$ 17.7	$ 15.4
TOTAL PRESENT COST (per m2)	$ 357	$ 457	$ 397
Concrete Road Footpath			
Construction (per m^2)	$ 77	$ 98	$ 85
Maintenance			
Average Annualised (per m^2)	$ -	$ -	$ -
TOTAL PRESENT COST (per m2)	$ 77	$ 98	$ 85

Table 3-7 Recommended Conventional Parking and Road Scenario Unit Rates

2,000m^2 Asphalt Parking Area (350mm base)			
Construction (for pavements, vegetated and rain gardens see above)			
- Other (kerb, piping, cesspits) for 2,000m^2 parking area	$ 20,340	$ 25,990	$ 22,600
Maintenance - Average Annualised (undiscounted)			
- Other (for 2,000m^2)	$ 2,373	$ 3,033	$ 2,637
TOTAL PRESENT COST (for 2,000m^2)	$ 69,218	$ 84,600	$ 76,909
40m Asphalt Local Road (400mm base)			
Construction (for pavements, vegetated and rain gardens see above)			
- Other (kerb, piping, cesspits) for 40m road length	$ 19,260	$ 24,610	$ 21,400
Maintenance - Average Annualised (undiscounted)			
- Other (for 40m)	$ 2,247	$ 2,872	$ 2,497
TOTAL PRESENT COST (40m)	$ 65,543	$ 80,109	$ 72,826
40m Asphalt Secondary Arterial Road (600mm base)			
Construction (for pavements, vegetated and rain gardens see above)			
- Other (kerb, piping, cesspits) for 40m road length	$ 33,480	$ 40,920	$ 37,200
Maintenance - Average Annualised (undiscounted)			
- Other (for 40m)	$ 3,906.0	$ 4,991.0	$ 4,340
TOTAL PRESENT COST (40m)	$ 113,935	$ 139,253	$ 126,594

Table 3-8 Recommended Household Conventional Surfaces Unit Costs

Concrete Household Driveway			
Construction (per m^2)	$ 95	$ 121	$ 105
Maintenance			
Average Annualised (per m^2)	$ -	$ -	$ -
TOTAL PRESENT COST (per m2)	$ 95	$ 121	$ 105
Concrete Household Paths			
Construction (per m^2)	$ 59	$ 75	$ 65
Maintenance			
Average Annualised (per m^2)	$ -	$ -	$ -
TOTAL PRESENT COST (per m2)	$ 59	$ 75	$ 65

4.0 Rain Water Tanks

4.1 Introduction

There is a wide range of rain water tank systems. To meet the Unitary Plan SMAF hydrology controls the tanks need to provide both detention of the small frequent rain fall events (less than the 2 year ARI) and retention (volume reduction). This means that the system needs to be a 'dual-purpose' rain water tank. A 'dual-purpose' tank is one that comprises two sections, one above and one below a small diameter orifice part way up the side of the tank, refer to Figure 4-1. The volume below the orifice is used primarily for rainwater harvesting purposes (for non-potable water uses such as toilet, washing machine and outdoor uses), while the volume above the orifice is used for detention. The orifice allows the slow release of roof run-off during and after rainfall events. Regular inspections are required to ensure the dual functions of the rain tank are not compromised by the owners.

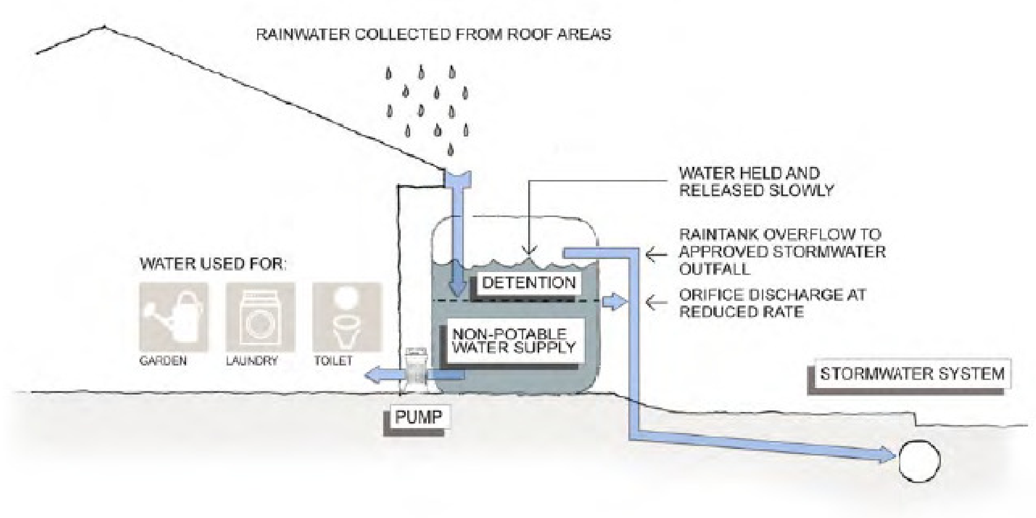


Figure 4-1 Typical Schematic for 'Dual-Purpose' Rainwater Tank System (North Shore City Council 2009)

4.2 Variability in Calculating Costs

Rain water tank costs can vary due to:

- Type of rain water tank system – as mentioned in the introduction, for the Unitary Plan only the 'dual-purpose' rain water tanks have been costed.
- Size of device – rain water tanks have a relatively fixed cost for installation, pump, piping and electrical and a variable cost for the size of rain tank. The larger the rain water tank the lower the unit cost per cubic metre of storage.
- Type of rain water tank – Rain water tanks come in different materials (HDPE, steel and concrete), sizes and shapes (round or rectangular/slimline). Rectangular/slimline tanks cost more than round tanks but can often fit in spaces that round tanks can not. For example, a 3,000 litre rectangular/slimline tank costs between $2,000 to $2,700, whereas a 3,000 litre round HDPE costs $1,000 with a 10,000 litre round HDPE costing $2,000.

- Type of installation – the installation of new systems is the least expensive with retrofitting costing significantly more depending on the existing plumbing and roof gutter collection system.

4.3 Costing Data Sources

Rain water tank costing sources are:

- Rain water tank suppliers
- Rain water tank installers
- Glencourt Place, North Shore, dual purpose rain water tank installation project on 20 houses.
- Landcare Research COSTnz Model – itemised unit rates for a 5,000 litre dual-purpose rain water tank system (www.costnz.co.nz, November 2012). COSTnz data is based on design, construction and maintenance techniques at the time of model development (2006).

4.4 Construction Costs

Table 4-1 shows itemised fixed costs for a typical dual-purpose rain water tank system from a local supplier/installer and the Landcare Research COSTnz Model for a comparable system, plus variable tank costs depending on the size and type of rain water tank.

Table 4-1 Itemised Rain Water Tank System Costs (local supplier/installer, reproduced with permission)

Item	COSTnz (Middle)	New Local Supplier/Installer		With Variable Tank Sizes (Local Suppliers)			
FIXED COST							
Design/consenting	$ 1,000	$ 500					
Earthworks/install							
- expose existing services	$ 675						
- site clearance	$ 1,500						
- pad (conc?)	$ 292						
Connections							
- house supply valves	$ 150						
- top up switch	$ 275	$ 3,450					
- first flush diverter	$ 600						
- tank vac							
- pump	$ 1,400						
- 32mm OD MPPE piping	$ 380						
- 110mm overflow	$ 475						
Electrical	$ 1,500	$ 500					
Subtotal	**$ 8,247**	**$ 4,450**	**$ 4,450**	**$ 4,450**	**$ 4,450**	**$ 4,450**	**$ 4,450**
Contingency (10%)	$ 825	$ 445	$ 445	$ 445	$ 445	$ 445	$ 445
Subtotal	**$ 9,072**	**$ 4,895**	**$ 4,895**	**$ 4,895**	**$ 4,895**	**$ 4,895**	**$ 4,895**
VARIABLE TANK COST							
Tank							
- 5,000litre	$ 1,525						
- 3,000 litre steel rectangle		$ 2,700					
- 7,000 litre steel rectangle			$ 4,500				
- 3,000 slimline HDPE				$ 1,854			
- 9,000 slimline HDPE					$ 5,391		
- 5,000 round HDPE						$ 1,039	
- 10,000 round HDPE							$ 1,774
TOTAL	**$ 10,597**	**$ 7,595**	**$ 9,395**	**$ 6,749**	**$ 10,286**	**$ 5,934**	**$ 6,669**

Cost of household dual purpose plumbing highly site specific, particularly if retrofit.

Cost of tank highly variable on size and type of tank (e.g. 3,000 litre round = $1,000, compared to slimline/rectangular of $2,200 to $3,000)

The COSTnz site gives a range of $8,600 (low), to $10,600 (middle as above), to $12,900 (high) for the 5,000 litre rain tank example, that is +/- 20%.

As noted above, the cost of the rain water tank system, especially for dual-purpose systems, is highly variable and site specific due to the size and type of tank (steel, HDPE, rectangular/slimlime or round), access constraints and amount of site preparation required. For example, COSTnz gives a site clearance cost range of $1,000 to $2,000. Whether it is a new installation or retrofit also significantly affects the cost as the dual-purpose systems need to be connected into the non-potable household plumbing. For example, the Glencourt Place rain water tank retrofit project showed dual-purpose rainwater installation costs including a typical 9,000 litre rain water tank were in the range of $7,500 to $10,000 per house.

Table 4-2 summarises the range of recommended rain water tank system construction costs from the above sources.

Table 4-2 Recommended Range of Rain Water Tank System Construction Costs

<table>
<tr><th rowspan="2">Rain Tank Size (litres)</th><th colspan="2">Dual-Purpose Rain Tank System</th><th rowspan="2">Explanation</th></tr>
<tr><th>New</th><th>Retrofit</th></tr>
<tr><td></td><td>$6,500</td><td>$8,500</td><td>Fixed cost for plumbing, pump etc, plus another $1,000 for site works.</td></tr>
<tr><td colspan="4">Assume minimum tank size for dual-purpose system is 5,000 litres</td></tr>
<tr><td>5,000</td><td colspan="2">$1,100</td><td>For minimum 5,000 litre round HDPE tank.</td></tr>
<tr><td>10,000</td><td colspan="2">$2,000</td><td>For up to 10,000 litre round HDPE tank.</td></tr>
<tr><td rowspan="2">TOTALS (Range)</td><td>$7,600</td><td></td><td>For 5,000 litre tank</td></tr>
<tr><td></td><td>$10,500</td><td>For 10,000 litre tank</td></tr>
</table>

For the costing model, it is recommended to use a range of rain water tank costs of (assume these costs include any design/construction drawing requirements and contingencies):

- Low - $7,500 for new 5,000 litre round HDPE dual-purpose system.
- High - $10,500 for retrofit 10,000 litre round HDPE dual-purpose system.

4.5 Maintenance Costs

The Landcare Research COSTnz Model gives the following maintenance items for a typical dual-purpose system with a 5,500 litre tank:

Routine inspections:

- Inspection of tank, orifice outlet, pipework, first flush device, pest screens, erosion protection, at $120 (low - 2 per year at $60) to $200 (high – 2 per year at $100).
- Inspection of water supply pumps and associated electrical work, at $30 (1 per year at $30) to $60 (1 per year at $60).
- TOTAL Inspections from Low of $150 to High of $260 per year.

Routine maintenance:

- Clean out dead storage (i.e. Removal of sediment from tank and repairs as necessary), $165 (low - 1 per year at $165) to $168 (high – 1 per year at $168).
- Make good following vandalism, $20 (low – 1 per year at $20) to $25 (high – 1 per year at $25).
- Maintenance and replacement of screens/filters, $200 (low – 2 per year at $100) to $250 (high – 2 per year at $125).
- TOTAL Routine maintenance from Low of $385 to High of $443 per year.

Council Inspection:

- Allow additional for one Council inspection at $100 per year for first three years, then $100 once every three years thereafter.

Corrective Maintenance:

- Maintenance of water supply pumps and associated electrical work, 1 per 5 years at $90 (low) to $100 (high).
- Replacement of water supply pump, 1 per 10 years at $1,000 (low) to $2,500 (high).
- Minor repairs to concrete and structural components (e.g. sealing cracks, tank stand etc.), 1 per 10 years at $100 (low) to $500 (high).
- Replacement tank – HDPE tanks have a 25 year warranty. COSTnz includes a replacement rain tank system after 35 years. Allow for replacement tank, plumbing and electrical work of $2,500 for tank, $1,000 plumbing and $500 electrical work, TOTAL of $4,000 every 35 years.

Table 4-3 summarises the recommended low and high range maintenance costs.

Table 4-3 Rain Tank System Costs Used for Whole Life Costs

ITEM	Low	High
Routine Inspections/Maintenance		
Council inspection one per year for first three years, then once per three years thereafter.	$100 per year for three years, then $100 every three years thereafter.	
Routine Inspections – one inspection per year for the tank, pump, electrical and cleaning screens.	$100 per year	$250 per year
Routine Maintenance - Removal of sediment from tank and repairs/maintenance as necessary every 3 years.	$300 every 3 years	$450 every 3 years
Corrective Maintenance		
Water supply pumps and associated electrical work every 5 years.	$150 every 5 years	$250 every 5 years
Replacement of water supply pump every 10 years.	$1,000 every 10 years	
Replacement tank and associated plumbing and electrical work	$3,500	$4,000

4.6 Water Savings

A further refinement of the total present costs for rain tanks is to take into account the reduced water bill charges from using rainwater for non-potable uses. For households rain water can be used for toilet, laundry and outdoor uses. For commercial/industrial sites rain water can be used for toilets (based on building occupancy) and/or industrial water uses where potable water is not required.

Clearly the water savings are a function of the rainfall distribution, size of the roof, size of the rain water tank and actual water usage. Due to the variability, commercial/industrial sites need site specific analysis. While there is still a wide variation for households, for demonstration purposes, a 'typical' household using rain water for toilets, laundry and outdoor has been used for costing assumptions. The water use of a 'typical' household has been estimated from two sources. First, studies have shown that households use approximately 25% of the total water demand for toilets, 20% for laundry and up to 20% for the garden, giving a total potential savings of up to 65%. If assume an approximate 50%, given the highly variable garden use, and an average household water use of 500 litres per day, equates to 250 litres per day saving.

The second source of water usage is the previous North Shore City Council Glencourt Place Rain Tank project. This project included the installation of 21 dual purpose rain water tanks in and around Glencourt Place in 2005. Water meter readings over the period from 2003 (before the installation of the rain tanks) through to 2007 (two years after the rain tanks were installed) showed a wide variation of total household water use, varying from 200 to 750 litres per day, with an average of 450 litres per day. After the installation of the rain water tanks the average water consumption was reduced to 250 litres per day, an average saving of 200 litres per day. For costing purposes, the more conservative 200 litres per day savings has been used.

To account for the savings from a reduction in the household water bill the total present cost calculations have added the following:

1. Residential water charge savings – as of 1 July 2013, Watercare charge a water supply volumetric charge of $1.343 per 1,000 litres (Watercare 2013).
2. Cost of power to run the household water pump to deliver the water from the rain tank. Previous discussions by Kettle with suppliers have indicated yearly power consumption of approximately $40 per year.

The 200 litres per day savings adds up to a savings of $73m^3$/year, at $1.343 per m^3, equating to a savings of $98 per year. Subtracting the cost of power to run the water pump of $40 per year gives a net savings of $58/year.

4.7 Total Present Costs

Table 4-4 summarises the 'low' and 'high' range of construction, maintenance and total present costs for dual-purpose rain tanks. Total present costs have been calculated for a 60-year appraisal period using a real discount rate of 4%.

Total present costs have been estimated using the recommended construction and maintenance costs from the above two sections.

The values in the following table have been used as the unit rates to estimate the 'scenario' costs in the main report.

Table 4-4 Recommended Rain Water Tank Unit Costs

RAIN WATER TANKS	**Low**	**High**
Costs per house, with 10,000 litre tank		
Construction (per house)	$ 7,500	$ 10,500
Maintenance		
Average Annualised (per house)	$ 425	$ 645
TOTAL PRESENT COST (per house)	$ 16,250	$ 24,150

5.0 Living Roofs

5.1 Introduction

Costs have been estimated for living roofs as they can provide significant stormwater and other benefits, such as insulation, energy savings from reduced heating/cooling and aesthetics. Living roofs comprise vegetation growing in a substrate on top of a waterproof and root resistant membrane. See Figure 5-1 for typical living roof components.

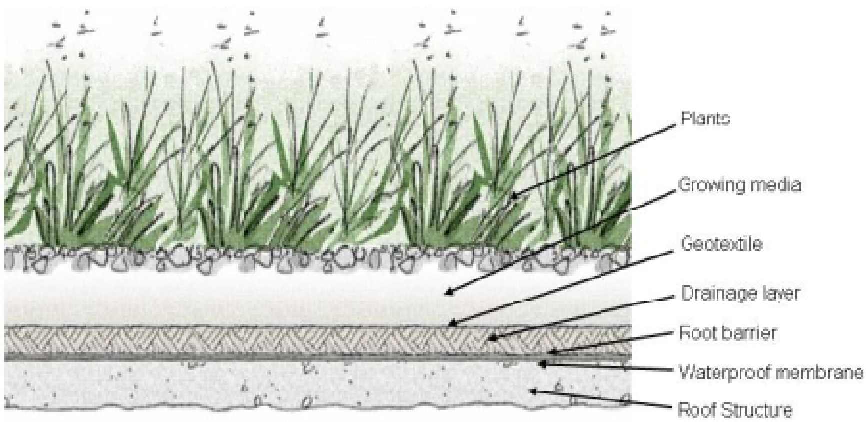


Figure 5-1 Typical Living Roof Components (Auckland Council 2011)

5.2 Variability in Calculating Costs

Living roof costs are dependent on:

- Size of roof – There is a relatively fixed cost for establishment etc., with a variable cost for the components. The costs below have been estimated for a roof area in the order of 200m^2.
- Type of living roof - Living roofs can have variable growing media thicknesses, varying from 50 to 75mm up to greater than 200mm. Costs below are for what is referred to as an 'extensive' living roof, with a media thickness of 75 to 100mm.
- Type of roof structure – As living roofs typically weigh more than conventional roofing materials, living roofs require professional design of additional structural support. The additional structural support is highly variable depending on roof type. Due to the wide variability, these additional structural costs have NOT been included in the costs below.

5.3 Costing Data Sources

Living roofs are relatively new and hence there is limited costing information available. The following roof estimated costs have been sourced from local roof suppliers/installers. Rawlinsons New Zealand Construction Handbook (2010) has also been used for estimating conventional roofing costs.

5.4 Construction Costs

Living roof estimated construction costs for a roof area in the order of $200m^2$ are:

- Drainage layer, growing media, plants and irrigation system: \$200 to \$400/m^2.
- Waterproof membrane, range of low for a two-layer and high for a triple layer: \$105 to \$165/m^2.
- SUBTOTAL for installation: \$305 to \$465/m^2.
- Plus optional waterproof testing: \$30/m^2 (see explanation below).
- TOTAL for installation and testing: \$335 to \$495/m^2.

Note that these costs do NOT include any additional structural roofing costs that may be required to support the weight of the living roof. These costs are highly variable depending on the type of roof.

Assuring the waterproof membrane is not punctured during the construction phase and does not develop leaks over the longer term is always a concern with living roofs. One option is to carry out 'Electric Field Vector Mapping (EFVM)'. To carry out EVFM testing of membrane over plywood (for the case of a house) requires a layer of stainless steel conductive mesh to be placed on the plywood, prior to the first layer of membrane. The EVFM testing can then locate any leaks by the change in directional flow of the current with sensors and can locate leeks within an accuracy of around +/- 0.3m for a typical living roof substrate. This leek testing can be carried out after installation of the membrane, after placement of the growing media and then for longer term testing at say, 30 yearly intervals. Costs received from a local installer indicates that for a house roof area of $200m^2$, the supply of the stainless steel mesh and accessories would cost approximately \$1,700 (\$8.50/m^2). Installation would cost an additional \$3 to \$10/m^2, for costing use \$5/m^2. Testing of the area would cost approximately \$1,500 (\$7.50/m^2) per test. Assume tested twice, once after membrane installation and again after installation of living roof. For installation and initial testing of constructed living roof assume total of \$5,700 (\$28.5/m^2), say \$30/m^2.

For standard roof use a supply and install price of \$60/m^2 (Rawlinsons 2010).

5.5 Maintenance Costs

Routine living roof maintenance costs are in the order of:

- First year: included in the construction cost.
- Year 2 – 3: ½ day monthly visit at \$250 per visit, \$3,000 per year.
- After 3 years: ½ day visit every 6 months at \$250 per visit, \$500 per year.
- Council inspections: allow one council inspection per year for first three years, then once every three years thereafter, at \$100 per inspection.

Note that the above routine maintenance costs have assumed a maintenance contract with a living roof specialist contractor. It is recommended that a specialist contractor is used for at least the first 3 years, thereafter the householder may be able to carry out their own maintenance provided they meet the health and safety regulations with respect to working at heights, and have the required horticultural experience.

Long term corrective maintenance costs are more difficult to quantify. Personal communication with membrane suppliers have noted that the warranty of the membrane can be extended with a living roof due to less exposure to the sun and elements compared to a conventional roof membrane. For example, a typical membrane warranty of 20 years could be extended up to 40 years if under a living roof.

Assume living roof corrective maintenance costs of:

- Every 10 years – 2-day replanting visit at $1,000 to $1,500
- Every 20 years – waterproof testing and some minor repairs of $10,500 to $13,500 (EFVM waterproof testing of $1,500 as above, plus $9,000 to $12,000 for repairs on 10% of roof area at a cost of 1.5 times living roof installation cost)
- Every 40 years – complete reconstruction of the roof at a cost of 1.2 times the initial construction cost (expected life of the membrane)

For a standard roof in a moderate environment (that is, not close to the coast), rain washing is generally sufficient to remove most accumulated atmospheric contaminants. Assume no on-going regular maintenance.

For standard roof corrective maintenance assume:

- Every 50 years - complete new roof at $80/m2 (Personal communication with roofing supplier indicates a cost of around $6/m2 to remove old roofing, plus cost to dispose. Disposal costs vary markedly between a concrete tile disposal to a landfill (for a 200m^2 roof, 10 tons of tile at $200/ton = $2,000, or $10/m^2) compared to a steel roof that can go to a steel recycler (at minimal cost as payment for steel is likely to offset transport costs). For costing purposes, assume a corrective maintenance cost of $6/m^2 to remove old roofing, plus dispose at $10/m^2 plus install new at $60/m^2, for total of $76/m^2, say $80/m^2.)

5.6 Total Present Costs

Table 5-1 summarises the 'low' and 'high' range of construction, maintenance and total present costs for a living roof. The table also includes the assumed costs for a standard roofing material, excluding the roof superstructure. Total present costs have been calculated for a 60-year appraisal period using a real discount rate of 4%.

Total present costs have been estimated using the recommended construction and maintenance costs from the above two sections.

The values in the following table have been used as the unit rates to estimate the 'scenario' costs in the main report.

Table 5-1 Recommended Living Roof Unit Costs

LIVING ROOF	Low	High
Costs for typical 200m^2 house roof		
Construction (per house)	$ 67,000	$ 119,000
Maintenance		
Average Annualised (per house)	$ 2,470	$ 3,250
TOTAL PRESENT COST (per house)	$ 108,000	$ 171,000
Standard roofing material		
Construction (per house)	$ 12,000	$ 12,000
Average annualised (per house)	$ 270	$ 270
TOTAL PRESENT COST (per house)	$ 14,250	$ 14,250

6.0 Sand Filters

6.1 Introduction

Costs have also been estimated for sand filters as they are a commonly used existing water quality treatment device (refer Figure 6-1).

Sand filters use filtration for treating stormwater. They are primarily water quality treatment practices, having little water quantity benefit. Sand filters are effective in removing hydrocarbons and for impervious surfaces where the majority of sediments are in the coarse fraction.

Figure 6-1 Construction of a Sand Filter (Healy et al 2010)

6.2 Variability in Calculating Costs

Sand filter costs are dependent on:

- Size of device – There is a fixed cost for establishment, connecting in to existing services, inlet/outlets, etc. with a variable cost per m^2 for excavation, the manufacture of the device and backfill etc.
- Site conditions – for example, a high water table could require dewatering during installation.

6.3 Costing Data Sources

Only one sand filter costing source was used:

- Landcare Research COSTnz Model cost estimating website. COSTnz data is based on design, construction and maintenance techniques at the time of model development (2006).

6.4 Construction Costs

Table 6-1 and Figure 6-2 summarise the costs from COSTnz over the range of standard size filtration units for catchment areas from 250 to 3,000m^2.

Table 6-1 Sand Filter Estimated Construction Costs (COSTnz 2012)

	COSTnz ($)		
Catchment Area (m^2)	**Low**	**Middle**	**High**
250	$27,000	$39,000	$54,000
1,000	$40,000	$56,000	$77,000
3,000	$60,000	$74,000	$91,000

Table 6-1 indicates a cost range of up to +/- 30 to 40% from the middle value.

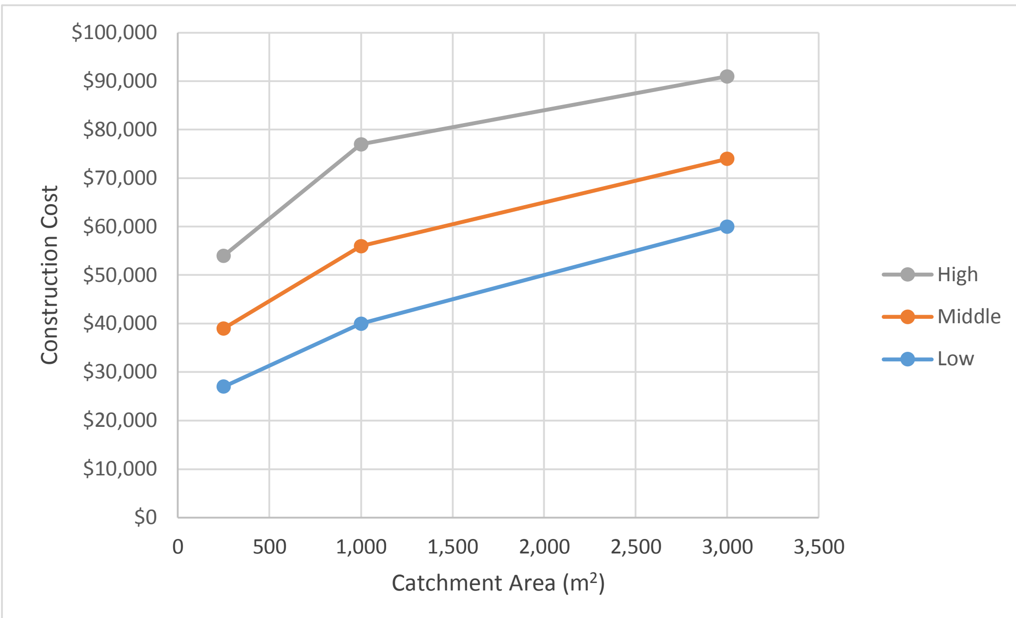


Figure 6-2 Sand Filter Estimated Construction Costs (COSTnz 2012)

Table 6-2 presents the sand filter construction cost estimation equations used for the total present costs.

Table 6-2 Sand Filter Construction Cost Equations (COSTnz 2012)

	COSTnz ($)		
Catchment Area (m^2)	**Low**	**Middle**	**High**
250 to 1,000	$22,000 + $20/$m^2$	$35,000 + $20/$m^2$	$47,000 + $20/$m^2$
1,000 to 3,000	$40,000 + $10/$m^2$ above 1,000m^2	$55,000 + $10/$m^2$ above 1,000m^2	$75,000 + $10/$m^2$ above 1,000m^2

6.5 Maintenance Costs

The Landcare Research COSTnz Model gives the following maintenance items for a typical 1,000m^2 catchment area (the middle maintenance cost is mid-way between low and high):

On-going maintenance:

- Routine general maintenance (removing debris, oil & grease, clearing inlets and outlets) 4 per year per filter at $200 (low – 4 at $50) to $400 (high – 4 at $100).
- Inspections (outlets/overflow spillway, general) 4 per year per filter at $400 (low – 4 at $100) to $612 (high – 4 at $153).
- Clean out filtration chamber and dispose of sediment, 2 per year per filter at $900 (low – 2 at $450) to $1,000 (high 2 at $500).
- Minor repairs 1 per year per filter at $50 (low) to $250 (high).
- TOTAL annual per filter = $1,550 (low) to $2,262 (high) per year (range of +/- 20% from middle cost of $1,900).

Corrective maintenance

- Removal and disposal of sediments from sedimentation chamber every 5 years at $250 (low – 0.5m^3 at $500/m^3) to $300 (high – 0.5m^3 at $600/m^3).
- Removal, disposal and replacement of sand filter media every 5 years at $1,600 (low – 3m^3 at $535/m^3) to $1,950 (high – 3m^3 at $650/m^3).
- Replacement of parts every 5 years per filter at $600 (low) to $1,000 (high).
- TOTAL corrective maintenance every 5 years = $2,450 (low) to $3,250 (high), (range of +/- 15% from middle cost of $2,850).
- Note, need to add on-going yearly maintenance (with 1, 2 and 4 actions per year) to 5 yearly corrective maintenance. Giving total 5-yearly cost of $4,000 (low), $4,750 (middle), and $5,512 (high).

For 3,000m^2 catchment assume same on-going maintenance at total annual per filter of $1,550 to $2,262 per year. For 5-yearly corrective maintenance assume increased removal and disposal of sediments from sedimentation chamber of 1m^3 per year, and 7m^3 from sand filter, with the same replacement of parts. This gives a 5-yearly corrective maintenance of $4,850 (low) to $6,150 (high), with a 'middle' cost of $5,500. Adding on-going maintenance, gives a total 5-yearly corrective cost of $6,400 (low), $7,400 (middle), and $8,412 (high).

6.6 Total Present Costs

Because of the significant cost efficiencies of sand filters with increasing area of treatment, the costs of indicative sand filters are given for treating 1,000m^2 and 3,000m^2 of impervious area.

Table 6-3 summarises the 'low' and 'high' range of construction, maintenance and total present costs for sand filters treating 1,000 and 3,000m^2. Total present costs have been calculated for a 60-year appraisal period using a real discount rate of 4%.

Total present costs have been estimated using the recommended construction and maintenance costs from the above sections.

The values in the following table have been used as the unit rates to estimate the 'scenario' costs in the main report.

Table 6-3 Recommended Sand Filter Unit Costs

SAND FILTER	**Low**	**High**
Treating 1,000m^2		
Construction	$ 40,000	$ 77,000
Maintenance		
Average Annualised	$ 2,040	$ 2,912
TOTAL PRESENT COST	$ 85,300	$ 141,749
Treating 3,000m^2		
Construction	$ 60,000	$ 91,000
Maintenance		
Average annualised	$ 2,520	$ 3,492
TOTAL PRESENT COST	$ 115,324	$ 167,862
Median Values for 2,000m^2 Parking Area		
Construction	$ 50,000	$ 84,000
Maintenance	$ -	$ -
Average annualised	$ 2,280	$ 3,202
TOTAL PRESENT COST	$ 100,312	$ 154,806

7.0 Wetlands

7.1 Introduction

Constructed wetlands have become increasingly popular in recent years for the improvement of water quality. Wetlands can be designed to accomplish a number of stormwater functions, including:

- Water quality treatment
- Flow detention/attenuation
- Flood protection

7.2 Variability in Calculating Costs

Wetland costs can vary due to:

- Design criteria – for water quality, detention and/or 100 year flood mitigation.
- Size of wetland – unit costs generally decrease with increasing wetland size.
- Amenity value – extent of walkways, boardwalks and perimeter landscaping.
- Structural elements – size and nature of inlet/outlet structures and the need for retaining walls if needed due to land constraints.
- Frequency of corrective maintenance (desilting forebay and main pond) is highly variable due to factors such as the maturity and particulate generation of the catchment and design of the wetland. In some cases it can be better to design the wetland for a two-phase life with an initial mode of operation during the subdivision, development and establishment phases of the catchment and then changing into a different mode once the catchment has matured.

7.3 Costing Data Sources

The following wetland costing sources were used:

- Totara Creek Stormwater ponds – Engineers Estimate based on construction drawings, construction scheduled for summer 2012/13.
- Long Bay Structure Plan – Awaruku Wetland as built costs, constructed 2011/2012.
- Landcare Research COSTnz Model – range of low to high based on input parameter of wetland permanent water surface area (www.costnz.co.nz, November 2012). COSTnz data is based on design, construction and maintenance techniques at the time of model development (2006).

7.4 Construction Costs

Figure 7-1 and Table 7-1 summarise the wetland costs from the above sources.

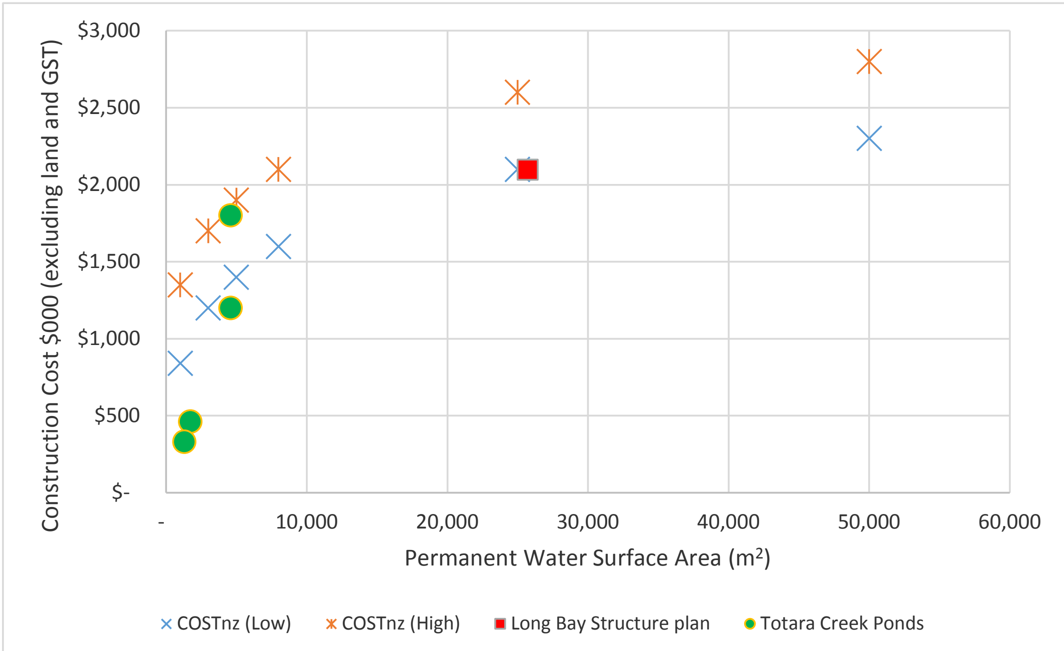


Figure 7-1 Graphed Wetland Costs vs Permanent Water Surface Area

Table 7-1 Example Wetland Costs vs Permanent Water Surface Area

Wetland ID	Permanent Water Surface Area (m^2)	Cost ($k)	Cost/m^2	Comments
Totara Creek Ponds				
Pond 2	4,600	$1,800	$391	Large outlet structure and feature crib walls
Pond 3	4,600	$1,200	$261	Large outlet structure
Pond 6	1,740	$462	$266	Basic Pond
Pond 7	1,310	$330	$252	Basic Pond
Long Bay Structure Plan				
Awaruku	25,700	$2,100	$82	Water quality pond only
COSTnz - Low	1,000	$840	$840	Full wetland with amenity values
	3,000	$1,200	$400	
	5,000	$1,400	$280	
	8,000	$1,600	$200	
	25,000	$2,100	$84	

Wetland ID	Permanent Water Surface Area (m^2)	Cost ($k)	Cost/m^2	Comments
	50,000	$2,300	$46	
COSTnz - High	1,000	$1,350	$1,350	Full wetland with amenity values
	3,000	$1,700	$567	
	5,000	$1,900	$380	
	8,000	$2,100	$263	
	25,000	$2,600	$104	
	50,000	$2,800	$56	

The above Figure 7-1 and Table 7-1 show a similar trend of decreasing wetland costs per m^2 with increasing permanent water surface area. These low and high costs vary approximately +/- 10 to 15% from the 'middle' cost. Clearly, for comparing with other stormwater treatment devices, the size of the wetland has a significant impact on its construction cost per m^2 of permanent water surface area, and hence the cost per m^2 of treated catchment area. For costing purposes the cost of a wetland servicing a 25 Hectare catchment (a permanent water surface area of 5,000m^2) has been chosen as a representative size for urban developments.

Figure 7-2 presents a plot of the wetland construction cost per square metre of catchment area versus the catchment area in hectares. This plot shows that the chosen 25 Ha catchment is close to the 'knee point' in the cost curve, prior to the significant increases in cost per square metre for smaller sized catchments. It gives a representative cost at the low end of a typical constructed wetland for moderately sized urban developments.

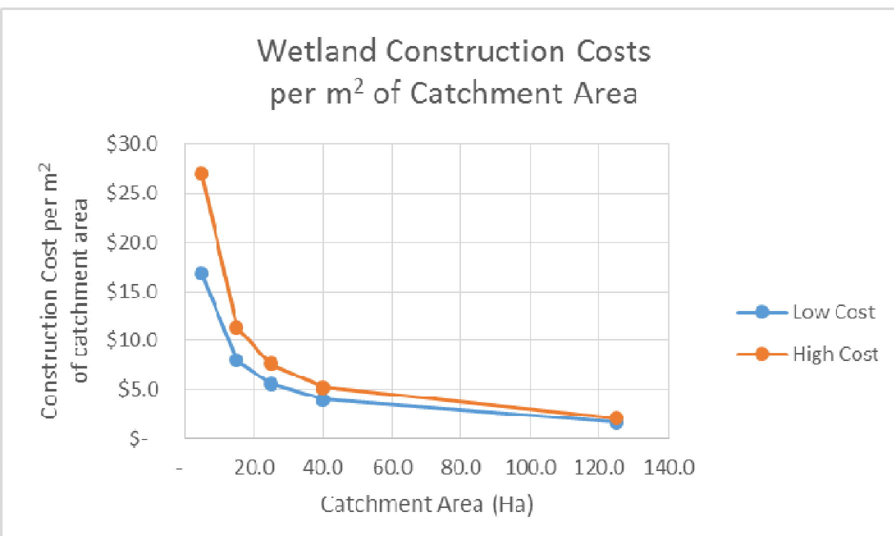


Figure 7-2 Wetland Construction Costs per m^2 of Catchment Area (COSTnz 2012)

7.5 Land Costs

For wetlands it is appropriate to include the cost of the land into the acquisition cost as wetlands are usually constructed on separate pieces of land zoned as stormwater management/open space land and can even take up developable land in some cases. It is best practice to locate wetlands outside the 100 year flood plain so they do not constrict the cross sectional geometry of the channel and so the erosive forces of the flood flows do not have the potential to resuspend the sediments within the wetland.

Other stormwater management devices such as bio-retention rain gardens and porous paving generally do not require additional land. Rain gardens are generally constructed within the developed land landscaping requirements. With porous paving there are no additional land costs as the porous surface is part of the standard paved surface.

Example land costs from a selection of projects are (excluding GST):

Drury South Business Park (DSBP) Private Plan Change 2012, undeveloped land outside the DSBP assigned area at $20/m^2, undeveloped land inside the DSBP assigned area at $50/m^2, developed commercial/industrial land at $300/m^2.

Riverhead – Greenfields rezoned from rural to residential with concept plan showing where stormwater reserves are required over the stream, floodplain and riparian margin, however this pond land was not shown on the concept plan so the valuation is higher to reflect that there was a loss of section yield from the total development potential. Note these are from Council's valuer and we are still waiting on the landowners' independent valuations which are usually higher:

- Pond Land, 8126m^2 at $451,000 'before and after basis' equates to $55/m2
- Stormwater reserve land, 3904m^2 at $141,000 'before and after basis' equates to $36/m^2
- Stormwater reserve land, 2935m2 at $95,000 'before and after basis' equates to $32/m^2

Babich – Greenfields rezoned from rural to residential with concept plan showing where stormwater pond and reserves are required over the stream, floodplain and riparian margin. We are only acquiring the pond land and easements for dam and ROW. There are already drainage easements over the floodplain on the underlying title:

- Pond land, 17,878m^2 + 4,770m^2 easement at $670,000 'before and after basis' equates to $20/m^2 and $5/m^2 for easement
- Pond land, 3,407m^2 at $65,000 floodplain 429m^2 valued at $5/m^2 and balance at $20/m^2

Flat Bush – District Plan rules included the amounts that would be paid for identified stormwater reserves and pond land, which are variable based on floodplain, existing vegetation, and slope. The values have to be based on raw undeveloped land:

- Rowan stormwater reserve/pond 35500m2 at $230,750 (signed in 2008) $6.50/m^2
- Floodplain at $6.50/m^2
- Steeper than 1:3 at $25/m^2
- Between 1:3 to 1:5 at $75/m^2
- Flatter than 1:5 at $145/m^2

Given the above information sources, a land value of $50/m^2 for the construction of wetlands has been suggested as representative of typical 'undeveloped' land that could be used within an urban environment for locating a wetland. Developed residential, commercial or industrial land would have a significantly higher land value of around $150 to $300/m^2, assume $300/m^2 for the 'high' range.

In estimating the land costs for wetlands an additional 10m width around the 'permanent water surface' has been allowed for the embankment top width and side slopes.

7.6 Maintenance Costs

For comparison, maintenance costs given by the Landcare Research COSTnz Model for two wetland sizes (permanent water surface areas of 1,000 and 5,000m^2) are summarised in Table 7-2.

Note that the corrective desilting costs and frequency are those received from Auckland Council Infrastructure & Environment Services. This information indicates:

- Desilting frequency of generally 10 to 30 years, use 20 years for costing.
- Desilting depths of 200 to 500mm, use 350mm for costing.
- Cost of desilting (including excavation, disposal to landfill, access way and dewatering) generally varies between $150 to $300/m^3 of silt.

Table 7-2 Wetland Maintenance Costs (COSTnz 2012)

Item	Cost (low to high)	Frequency	Unit	Water Surface Area (m^2)	
				1,000	5,000
Routine Maintenance					
Removing debris (e.g. litter, dead vegetation) from outlet and inlet structures	$40 to $137	12 per year	Per pond	$480 to $1,644	$480 to $1,644
Inspections (ducks, QA, inspection of embankments, spillways, outfalls, overall functioning of facility)	$250 to $400	1 per year	Per visit	$250 to $400	$250 to $400
Scheduled Routine Mechanical Maintenance (pumps, outlets, removing mosquito breeding areas)	$320 to $550	1 per year	Per pond	$320 to $550	$320 to $550
Make good following vandalism	$21 to $175	12 per year	Per pond	$252 to $2,100	$252 to $2,100
Weed management (on-going) (50% planting)	$0.25 to $0.29	1 per year	m^2	$125 to $145	$625 to $725
Initial Aftercare of Plants (for first 5 years) (50% planting)	$0.25 to $0.29	4 per year	m^2	$500 to $580	$2,500 to $2,900
Annual Total – first five years				**$1,930 to $5,420**	**$4,430 to $8,320**
				$1.93 to $5.42/m^2	**$0.89 to $1.66/m^2**

Item	Cost (low to high)	Frequency	Unit	Water Surface Area (m^2)	
				1,000	**5,000**
Annual Total – subsequent years				**\$1,430 to \$4,840**	**\$1,930 to \$5,420**
				\$1.43 to \$4.84/m^2	**\$0.39 to \$1.08/m^2**
Corrective Maintenance					
Corrective structural maintenance	\$10,000 to \$16,000	10 years	Per pond	\$10,000 to \$16,000	\$10,000 to \$16,000
Replacement of parts	\$1,000 to \$6,000	20 years	Per pond	\$1,000 to \$6,000	\$1,000 to \$6,000
Replanting the wetland zone (500m^2 or 4,000m^2)	\$9.00 to \$12.50	20 years	m^2	\$4,500 to \$6,250	\$22,500 to \$31,250
Desilting and disposal to landfill of forebay and main pond at cost of \$150 to \$300/m^3 (assume desilting depth of 0.35m, giving 350m^3 and 1,750m^3 for 1,000 and 5,000m^2 surface areas respectively)	\$150 to \$300/m^3	20 years	m^3	\$52,500 to \$105,000	\$262,500 to \$525,000
TOTAL every 20 years (including 10 year corrective structural maintenance)				\$68,000 to \$133,250	\$286,000 to \$562,250

For comparison, the annual maintenance unit cost database for SuDS (Royal HaskoningDHV 2012) gives a unit cost of £0.10/m^2, approx. NZ\$0.18/m^2 of wetland surface.

7.7 Total Present Costs

For comparison, the costs of wetlands with a 1,000m^2 and 5,000m^2 water surface area are presented below. Based on a wetland size of 2% of the catchment area, these wetlands serve catchment sizes of 5Ha and 25Ha respectively.

Table 7-3 summarises the ‘low’ and ‘high’ range of construction, maintenance and total present costs for wetlands with water surface areas of 1,000 and 5,000m^2. The ‘low’ costs are from the low construction and maintenance costs above, along with the low cost of land at \$50/m^2. The ‘high’ costs are for the high construction and maintenance costs above, along with the high cost of land at \$300/m^2. Total present costs have been calculated for a 60-year appraisal period using a real discount rate of 4%.

As mentioned previously, the values in the following table for the 5,000m^2 wetland (servicing a 25Ha catchment) have been used as the unit rates for the wetland – base case costs in the main report.

Table 7-3 Recommended Wetland Unit Costs

Wetland (1,000m^2, 5Ha catchment)	Low constr. (Low land $50/m2)	High constr. (High land $300/m2)
Construction (incl land)		
- Total	$ 985,000	$ 2,210,000
- per m2 catchment	$ 20	$ 44
Maintenance		
Average Annualised (per m2 catch)	$ 0.12	$ 0.26
TOTAL PRESENT COST		
- Total	$ 1,090,000	$ 2,453,000
- per m2 catchment	$ 22	$ 49

Wetland (5,000m^2, 25Ha catchment)	Low constr. (Low land $50/m2)	High constr. (High land $300/m2)
Construction (incl land)		
- Total	$ 1,665,000	$ 4,290,000
- per m2 catchment	$ 7	$ 17
Maintenance		
Average Annualised (per m2 catch)	$ 0.07	$ 0.15
TOTAL PRESENT COST		
- Total	$ 1,979,000	$ 4,913,000
- per m2 catchment	$ 8	$ 20

8.0 Gravel Storage /Retention

8.1 Introduction

Gravel with a high voids ratio of 40% voids (such as WAPP12 used for porous paving in Section 3.0, or equivalent) can be used for storage of stormwater runoff to allow for detention and infiltration into the underlying subsoils to meet the SMAF detention/retention requirements. Other underground storage methods such as plastic crates could also be used but are not covered in this appendix.

These SMAF retention/infiltration requirements are different to the conventional stormwater soakage device (soakholes and soakpits). Conventional soakage devices are for 'approved' soakage areas of Auckland City that do not have a piped stormwater network and rely on ground soakage for stormwater disposal of rainfall events up to the 1 in 10 year event. These 'approved' soakage areas generally have infiltration rates above 30mm/hr. Whereas, the SMAF design criteria are for the smaller more frequent events (up to the 1 in 2 year event) with temporary storage (detention) and longer term infiltration into the subsoils for the reduction of annual runoff volumes (retention). The SMAF areas can be in either low or high soil infiltration areas. In clayey soils, these SMAF detention/retention criteria function at infiltration rates as low as 1 to 3 mm/hr. SMAF areas with low infiltration capacity soils require a piped stormwater network to manage the excess flows up to the conventional 1 in 10 year event.

Whilst the objective of a SMAF storage/retention soakage device is different to that of a stormwater disposal soakage device, relevant conclusions and recommendations from TR 2013/040 *Stormwater Disposal via Soakage in the Auckland Region* have been incorporated into this section.

For the SMAF criteria, gravel storage/retention areas have only been considered for individual private house sites managing roof and driveway runoff. Two types of storage/retention devices have been costed:

- A standalone gravel storage chamber (generally a 1m thickness of gravel under 0.5m of soil cover)
- A greater thickness of gravel basecourse under a porous paving surface.

8.2 Variability in Calculating Costs

Gravel storage/retention costs can vary due to:

- Type of storage/retention system – whether a standalone gravel storage chamber or a greater thickness of gravel under a porous paving surface.
- Type of treatment area – the type of treated area determines the pre-treatment required before discharging into the gravel storage layer. Runoff from roof areas (with minor contaminants) should have leaf traps or similar to prevent the ingress of gross solids and organic materials (such as leaves). Runoff from driveways should have a sump/catchpit with a 'downturn pipe' to remove gross debris, floatables, leaves and coarse solids (sand/gravel and larger).
- Size and location of the device – if the storage gravel is constructed as part of another device, such as the porous paving, then there will be construction efficiencies with mobilisation and

the use of existing equipment on site. The larger the device may lead to cost efficiencies, however, the cost per m^3 of gravel is relatively constant.

8.3 Costing Data Sources

Costing sources included:

- Relevant unit costs used in the Bioretention Section 2 and Porous Paving Section 3.
- Rawlinsons New Zealand Construction Handbook, 2010.

8.4 Construction Costs

8.4.1 Gravel Storage Chamber

Construction costs for a 1m thickness of gravel, under 0.5m of soil cover are given in Table 8-1 for both roof and pavement runoff.

Table 8-1: Gravel Storage Chamber Unit Costs

Description	Unit	Quantity	Rate	Value
FOR ROOF RUNOFF				
COSTS per m^2 of storage chamber				
Excavate/stockpile	m^3	0.5	\$25	\$12.50
Excavate/dispose	m^3	1.0	\$50	\$50
Gravel - uncompacted (supply/place)	m^3	1.0	\$90	\$90
Backfill excavated material	m^3	0.5	\$25	\$12.50
Piping – (underdrain and connections, assume 1m pipe per m^2 of trench)	m	1.0	\$40	\$40
TOTAL per m^2 of gravel storage chamber area				**\$205**
FIXED COST (per device)				
Leaf traps, or similar, to remove gross solids/leaves				\$400
Allowance for using design ‘practice notes’				\$250
Observation Well (100mm dia perforated pipe)				\$300
TOTAL fixed				**\$950**
FOR PAVEMENT RUNOFF				
COSTS per m^2 of storage chamber				
Construction of gravel storage as per ‘roof runoff’				\$205
TOTAL per m^2 of gravel storage chamber area				**\$205**

FIXED COST (per device)				
Sump/catchpit with downturn pipe				$750
Allowance for using design ‘practice notes’				$250
Observation Well (100mm dia perforated pipe)				$300
TOTAL fixed				**$1,300**

8.4.2 Greater Thickness of Gravel under Porous Paving Driveway

Construction costs for a greater thickness of gravel under a porous paving driveway are given in Table 8-2 for both roof and pavement runoff.

Table 8-2: Greater Gravel Thickness under Porous Paving Unit Costs

Description	Unit	Quantity	Rate	Value
FOR ROOF RUNOFF				
COSTS per m^3 of additional gravel				
Excavate/dispose	m^3	1.0	$50	$50
Gravel – compacted (supply/place)	m^3	1.0	$110	$110
TOTAL per m^3				**$160**
FIXED COST (per device)				
Leaf traps, or similar, to remove gross solids/leaves				$400
Allowance for using design ‘practice notes’				$250
TOTAL fixed				**$650**
FOR PAVEMENT RUNOFF				
COSTS per m^3 of additional gravel				
Excavate/dispose	m^3	1.0	$50	$50
Gravel – compacted (supply/place)	m^3	1.0	$110	$110
TOTAL per m^3				**$160**
FIXED COST (per device)				
Note: No additional pre-treatment costs as porous paving provides treatment.				
Allowance for using design ‘practice notes’				$250
TOTAL fixed				**$250**

8.5 Maintenance Costs

8.5.1 Gravel Storage Chamber

Gravel storage chamber maintenance requirements have been adapted from the Auckland Council Soakage Design Manual and to be consistent with the other on-site devices costed in this appendix.

- As per household rain garden assume most of routine general maintenance (checking for debris accumulation, blockages and leaks) carried out by owner and corrective maintenance of replacing media not required for gravel storage due to low contaminant levels.
- Allow for council inspection or plumber/drainlayer inspection including checking of water level in the inspection well, one per year for first three years, then once every three years thereafter at $150 per visit (increased from $100 for council inspections of other on-site devices to allow for additional inspection requirements for the gravel soakage device).
- Allow for minor repairs, replacement of leaf traps, $500 every 5 to 10 years for roof runoff.
- Allow for minor repairs, removing sediment, $750 every 5 to 10 years for sump/catchpit for pavement runoff.

8.5.2 Greater Thickness of Gravel under Porous Paving Driveway

Use similar porous paving maintenance items as per Section 3.0 Porous Paving for small 'in-lot' installations such as driveways, as greater thickness of gravel will have minimal impact on maintenance regime. The only addition to the Section 3 porous paving maintenance is for the leaf traps or similar to prevent the ingress of gross solids and organic materials from the roof runoff.

Thus giving the following maintenance costs:

- From Section 3.5: For small 'in-lot' installations, (such as driveways),
  - End of first year and every ten years - Top up of joint chip between pavers at $5.50/m^2 (average thickness of 5mm @$100/m^3 = $0.50/m^2, plus installation @ $5/m^2, plus joint chip stabilisation additive @ $5/m^2,for a total of $10.50/m^2).
  - No cost of general inspection carried out by owner, but allow $100 for council inspections every year for first three years, then once every three years thereafter.
  - Every year - General cleaning/weed control @ $1/m^2 to cover possible incidentals for cleaning.
  - Assume no corrective maintenance to uplift and dispose of sand bedding and geotextile due to low loading levels.
- Allow for minor repairs, replacement of leaf traps, $500 every 5 to 10 years for roof runoff.

8.6 Total Present Costs

The following tables (Table 8-3 and Table 8-4) summarise the 'low' and 'high' range of construction, maintenance and total present costs for the gravel storage chamber and greater thickness of gravel porous paving options, respectively. Total present costs have been calculated for a 60 year appraisal period using a real discount rate of 4%. Note that the low and high range of construction costs were estimated using a likely distribution from a median cost of minus 10% for low, and plus 20% for high. The range of maintenance costs have been estimated using actual low and high range of costs.

Total present costs have been estimated using the recommended construction and maintenance costs from the above sections.

The values in the following tables have been used as the unit rates to estimate the 'scenario' costs in the main report.

Table 8-3: Recommended Gravel Storage Chamber Unit Costs

GRAVEL STORAGE CHAMBER	Low (-10%)	High (+20%)	Median
For Roof Runoff			
Construction			
- Fixed (per device)	$ 855	$ 1,140	$ 950
- Variable (per m^2)	$ 185	$ 246	$ 205
Maintenance			
Average Annualised (per device)	$ 105	$ 155	
TOTAL PRESENT COST			
- Capital Costs	Equal to Construction Cost		
- Maintenance Costs (per device)	$ 2,300	$ 3,500	
For Pavement Runoff			
Construction			
- Fixed (per device)	$ 1,170	$ 1,560	$ 1,300
- Variable (per m^2)	$ 185	$ 246	$ 205
Maintenance			
Average Annualised (per device)	$ 130	$ 205	
TOTAL PRESENT COST			
- Capital Costs	Equal to Construction Cost		
- Maintenance Costs (per device)	$ 2,800	$ 4,500	

Table 8-4: Recommended Greater Thickness of Gravel Porous Paving Unit Costs

GREATER THICKNESS GRAVEL POROUS PAVING per m^3 additional gravel	Low (-10%)	High (+20%)	Median
For Roof Runoff			
Construction			
- Fixed (per device)	$ 585	$ 780	$ 650
- Variable (per m^3)	$ 144	$ 192	$ 160
Maintenance			
Average Annualised (per device)	$ 50	$ 100	
TOTAL PRESENT COST			
- Capital Costs	Equal to Construction Cost		
- Maintenance Costs (per device)	$ 950	$ 2,100	
For Pavement Runoff			
Construction			
- Fixed (per device)	$ 225	$ 300	$ 250
- Variable (per m^3)	$ 144	$ 192	$ 160
Maintenance			
No additional above porous paving	$ -	$ -	
TOTAL PRESENT COST			
- Capital Costs	Equal to Construction Cost		
- Maintenance Costs (above porous paving)	$ -	$ -	

9.0 Water Sensitive Design

This section provides background information on the construction cost comparison of WSD for greenfield developments summarised in Section 2.10 of the main report.

In UK, WSD is termed as Sustainable Drainage Systems (SuDS) and Low Impact Development (LID) in USA.

9.1 Construction Cost Comparison

9.1.1 New Zealand and USA

A literature review of three New Zealand LID sites and six USA LID projects was carried out for the Auckland Regional Council (Shaver 2009). Clearly, the costs depend on an effective, thoughtful design approach but a key outcome is that LID can provide for a community that incorporates additional amenities and open space, and one that reduces impacts to natural systems generally with no additional construction costs.

Table 9-1 gives a summary of the total area, number and size of lots and the stormwater management for each of the different projects. Table 9-2 summarises the conventional and LID development construction costs.

Table 9-1 Case Study Developed Site Parameters (Shaver 2009)

Site	Area (ha)	Conventional Development			LID Development		
		No. of Lots	Av. Size (m^2)	Stormwater Management	No. of Lots	Av. Size (m^2)	Stormwater Management
New Zealand							
Heron Point	7.4	100	760	One large pond	104	650	Swale and two smaller ponds
Palm Heights	27.7	297	600	One large pond	275	511	Swale and two smaller ponds
Wainoni Downs	14.2	128	766	One large pond	138	651	Two wetlands
USA							
Chapel Run	40	142	2,000	Three ponds	142	1,000	Swales and infiltration
Buckingham Green	7.7	55	600	Two ponds	55	clusters	Swales and infiltration
Tharpe Knoll	13.4	23	4,000	Stormwater basin and wetland	23	clusters, 2,000	Swales and revegetation
Pleasant Hill	34	90	1,700	Three stormwater basins	90	clusters, 900	Swales and revegetation

Site	Area (ha)	Conventional Development			LID Development		
		No. of Lots	Av. Size (m^2)	Stormwater Management	No. of Lots	Av. Size (m^2)	Stormwater Management
Gap Creek	52	WSD principles included streets at natural grade, preservation of native vegetation and natural features drainage and network of buffers/greenbelts.					
Auburn Hills	34	Clustered design reduced length and cost of roads and stormwater management was via vegetated swales.					

Table 9-2 Comparison of Construction Costs between Conventional and LID Site Development (adapted from Shaver 2009)

Project	Total Development Costs		Conventional development	LID development	Percentage Difference
	Conventional development	LID development	($/Ha)	($/Ha)	
New Zealand					
Heron Point	1,844,000	1,590,000	$249,189	$214,865	14%
Palm Heights	7,218,000	5,936,000	$260,578	$214,296	18%
Wainoni Downs	5,963,000	4,478,000	$419,930	$315,352	25%
USA					
Chapel Run	2,460,200	888,735	$61,505	$22,218	64%
Buckingham Green	541,400	199,692	$70,312	$25,934	63%
Tharpe Knoll	561,650	339,715	$41,914	$25,352	39%
Pleasant Hill	1,284,100	728,035	$37,768	$21,413	43%
Gap Creek	4,620,600	3,942,100	$88,858	$75,810	15%
Auburn Hills	2,360,385	1,598,989	$69,423	$47,029	32%

Construction cost savings are in the order of 14-25% in New Zealand and 15-64% in USA. With higher uptake, it is probable that the cost of WSD developments will reduce in New Zealand.

In addition, the three Auckland subdivisions also had an estimation of a developers allowance for profit and risk to assess the feasibility of each scenario (refer Table 9-3).

Table 9-3 Gross Realisation for the Three Auckland Projects (Shaver 2009)

Project	Conventional development valuation (%)	LID development valuation (%)
Heron Point	39	38
Palm Heights	26	18
Wainoni Downs	15	23

From a financial perspective, only one of the three LID designs had a significantly less desirable outcome for the developer. That case study, Palm Heights, had significantly smaller lots with LID to protect watercourses, and it was anticipated that there would be less demand for those smaller sites in a greenfield area. Conversely Wainoni Downs had significantly greater Gross Realisation.

9.1.2 United Kingdom

As part of the work carried out for the UK Committee for Climate Change Adaptation, Royal HaskoningDHV (2012) looked at *'the type and scale of SuDS that would be cost-effective for society to take in England today for new and existing developments, when accounting for future climate uncertainty.'*

The report presented capital costs obtained from case study examples of new developments for a range of development size and densities, refer to Table 9-4 (the costs have been multiplied by 1.8 to convert from UK£ to NZ$).

Table 9-4 Capital Cost of SuDS and Traditional Drainage Systems (adapted from Royal HaskoningDHV 2012)

Development Density	Capital Cost per Property (NZ$)					
	Small (<100 properties)		Medium (100–500 properties)		Large (> 500 properties)	
	SuDS	Standard	SuDS	Standard	SuDS	Standard
Dense (urban) (100 properties per Ha)	No data	No data	900	1,800	No data	No data
Moderate density (40 properties per Ha)	10,000	11,000	2,000 – 8,000	5,500 – 9,000	2,000	No data

Table 9-4 illustrates that the costs of SuDS and traditional development decreases with development size as economies of scale are realised while costs reduce for higher density developments. It also shows that the construction cost of the SuDs option is cheaper to install for small and medium development.

The report listed the following summary of factors affecting the costs of SuDS (Royal HaskoningDHV 2012, p3):

- *Soil type: excavation costs are higher on rocky soils and the opportunity to implement infiltration solutions varies;*
- *Groundwater vulnerability: in vulnerable areas some SuDS measures will need impermeable liners to prevent infiltration which will increase costs;*

- *Design criteria: more stringent requirements for run-off control will lead to larger and more SuDS measures in the system;*
- *Design features: extensive planting is more expensive than SuDS measures that are allowed to colonise naturally;*
- *Access issues and space requirements: some measures take up land that would otherwise be used for development;*
- *Location: regional variations in labour and material costs, topography, soil conditions including permeability and local rainfall characteristics will affect design criteria;*
- *System size: larger schemes offer the opportunity for economics of scale to be realised; and*
- *New build or retrofit: the cost of installing a SuDS solution into an existing development involves very different costs to one designed as part of a new development.*

In summary, the report concluded with (Royal HaskoningDHV 2012, p20):

- *'In most situations SuDS have been shown to be less expensive to install and maintain than a traditional drainage system.*
- *All new development where site specific constraints do not lead to excessive cost implications should find it cost beneficial to install a SuDS system in preference to a traditional drainage system.*

10.0 Benefits/Values

This section provides additional information on benefits and values summarised in Section 3.2 of the main report.

10.1 Discussion on Values

Values have been assessed and discussed in a range of literatures. Value is contextual - it means different things to different people, and hence the difficulty in assigning a monetary value.

A range of ecological, social, cultural (not specific to tangata whenua) and economic values for freshwater from academic literature and New Zealand local government and consultancy reports are summarized in a recent Auckland Council report (McFarlane 2013).

The report highlighted the range of values that have been attributed to freshwater systems. The values include 'in-stream' (i.e. where the water remains in the water body) and 'out-of-stream' (where the water is abstracted or taken out of the water body). Not all of the values and attributes listed in Table 10-1 will be appropriate for all Auckland freshwater bodies. For example, energy generation values are only relevant to some freshwater bodies in Auckland. The value and attribute lists should be refined for each catchment, based on each value type's relevance to freshwater in that geographic area.

It is acknowledged that further work is required to transform the internationally and nationally derived values and valuation approaches summarised in this report into locally meaningful value frameworks for Auckland.

Table 10-1 Summarised list of freshwater values identified in the literature (adapted from McFarlane 2013)

	Value type	Value and attributes	
In-stream ecological values	Natural character values	1. Physical character: • water body size and shape • water body type/pattern • water quality • hydrological functioning • substrate and sediment processes • geodiversity (geological and geomorphic features) • surrounding landscape and boundaries • significant/outstanding natural features or landscapes • representativeness • rarity • vulnerability to damage • connectivity/distance to nearby water bodies	2. Naturalness: • intactness • physical modification of water body • soil erosion • naturalness of bank vegetation • development of floodplains, slopes, & visible uplands • parallel roads – length and type • crossings – bridges and fords • land use impacts

	Value type	Value and attributes

	Biological values	1. Species present (aquatic and terrestrial):
		• native birds
		• native fish
		• native invertebrates
		• indigenous vegetation
		• remnant vegetation
		• salmonids
		• rare/unique species
		• threatened species populations
		  ○ refugia for continued existence
		  ○ commercial opportunity cost
		• management of pest species
		2. Habitat types:
		• significant habitat of indigenous fauna and flora
		• significant habitat of trout and salmon
		• threatened species habitat
		• supports animal movement
		• breeding ground
		3. Habitat attributes:
		• representativeness
		• life supporting capacity
		• structural diversity
		• distinctiveness
		• intactness/naturalness
		• long term viability
		4. Ecosystem attributes:
		• representativeness
		• rarity
		• special features (species, ecotypes)
		• connectivity
		• naturalness
		• biodiversity/species richness
		• life-supporting capacity
		• ecological health
		• productivity
		• fragility and threat
		• long-term viability

In-stream social values	Aesthetic values	1. Biological features: • vegetation (volume, type and distribution) • wildlife/fauna • in-stream biodiversity • corridor biodiversity 2. Physical features – water body: • shape and size • channel type/ pattern/configuration • channel sinuosity • no. of tributaries • bed material • bank erosion • width of floodplain • presence of rapids and falls • evidence of modification by people 3. Hydrological features: • presence/ absence of water • low flow and average discharge • variability in depth & Flow • water clarity • water colour • smell • visible water movement 4. Physical features - wider landscape: • geology • landscape structure and pattern • valley area • valley height to width ratio • views • aesthetic diversity • wilderness • naturalness • ambience • peacefulness 5. Anthropological features • presence/amount of litter • artificial control structures • utilities, bridges, roads • urbanisation • historical features • land use type and intensity

	Value type	Value and attributes	
	Recreational values	1. recreational activity uses: • recreational fishing (including angling, whitebaiting) • camping • swimming • non motorized boating (sailing, kayaking, rowing) • motor water sports • hunting • hiking and walking • bird watching • picnicking 2. water body attributes: • size • supply of recreational resource • water quality • channel features • flow strength • temporality of flow conditions supporting recreation • abundance and size of target species • safety • skill or challenge factor • unique conditions	3. landscape attributes: • scenic appeal • natural appeal • peacefulness • other people you meet 4. recreational use: • frequency • Intensity 5. location - suitability for activity: • Travel time • Facilities • Accommodation • Accessibility • Problems /obstructions to use • Proximity to demand
	Cultural values (not specific to tangata whenua)	1. Heritage value: • Historical site/features • Archeological site/features 2. Education value: • Curriculum-based learning • Life-long learning 3. Access values: • transport • open space	4. Contribution to social wellbeing: • spiritual renewal cultural health • community identity (sense of place) • community connectedness • social interaction • local employment 5. Effects on personal health: • food source • physical health – long term • physical health – point exposure • mental health
In-stream economic values	Tourism values	1. number of water-body based tourist activities 2. number of international tourists undertaking water-based activities 3. number of domestic tourists undertaking water-based activities 4. scenic value	5. site significance: • geopreservation site (international/national/regional) • RAMSAR wetlands european heritage site • indigenous sites 6. iconic value: • opportunities for commercial premium • charitable sponsorship • National/Global obligations

	Value type	Value and attributes	
	Energy generation values	1. Hydroelectric energy generation: • existing generation in catchment • potential generation in catchment 2. Geothermal energy generation: • existing generation from geothermal fields • potential generation from geothermal fields	3. Impacts of generation: • impacts on the landscape • impacts on wildlife • impacts on pollution levels • creation of long-term employment opportunities • change in electricity prices
	Supply value	1. aquaculture	2. gravel extraction
	Research value	1. Research opportunities: • Commercial R&D	• 'Public good' research
	Land holder values	1. Effect on property values 2. Property risk management • flood mitigation • firebreaks • pest control	3. Stock access: • shade and shelter • grazing • stock drinking water
	Regional ecosystem service values	1. Hazard control • flood mitigation • erosion control 2. Maintenance of water quality • pollution dilution • filtration • water treatment (absorption of nutrients etc)	3. Soil enhancement • soil fertilization • nutrient retention • sediment retention 4. Groundwater replenishment 5. Stormwater regulation
Out-of-stream social values	Water supply values	1. Potable water source: • human consumption with treatment • human consumption without treatment	2. Water supply for fire fighting

	Value type	Value and attributes
Out-of-stream economic values	Water supply values	1. Economic value of water supplied for domestic uses from each catchment • human consumption with treatment • human consumption without treatment • future domestic water use 2. Economic value of water supplied for commercial and industrial uses from each catchment 3. Economic value of water supplied for agricultural uses from each catchment • irrigation o aggregate area irrigated by each water body o net contribution of irrigation to farmgate GDP o value of premiums paid for land due to water consents • stock drinking water supply • farm dairy water 4. Economic value to land holder: • Access to licensed water entitlements • Water infrastructure and management costs • Opportunities for enterprise diversification

10.2 Quantifying Values/Benefits

10.2.1 Four Interests Approach

The Ministry of Business, Innovation and Employment (MBIE) is funding a research project that uses the four interests approach (environmental, social, economic and cultural). The Urban Planning that Sustains Waterbodies (UPSW) project is part of a wider multi-institutional and multi disciplinary collaboration, the 'Resilient Urban Futures' research programme, and involves the development of a pilot decision support system (DSS) that allows urban planners and stormwater managers to consider holistically the impacts of urban development on indicators of environmental, social, economic and cultural wellbeing (Moores et al., 2013).

The current version of the DSS incorporates indicators of environmental, economic and social wellbeing. An aim of its further development is to also incorporate indicators of cultural wellbeing. The DSS links a number of distinct models and other methods in order to make predictions of outcomes under alternative urban development and stormwater management scenarios. Figure 10-1 below shows the structure (and linkages) of the pilot DSS (Moores et al., 2013).

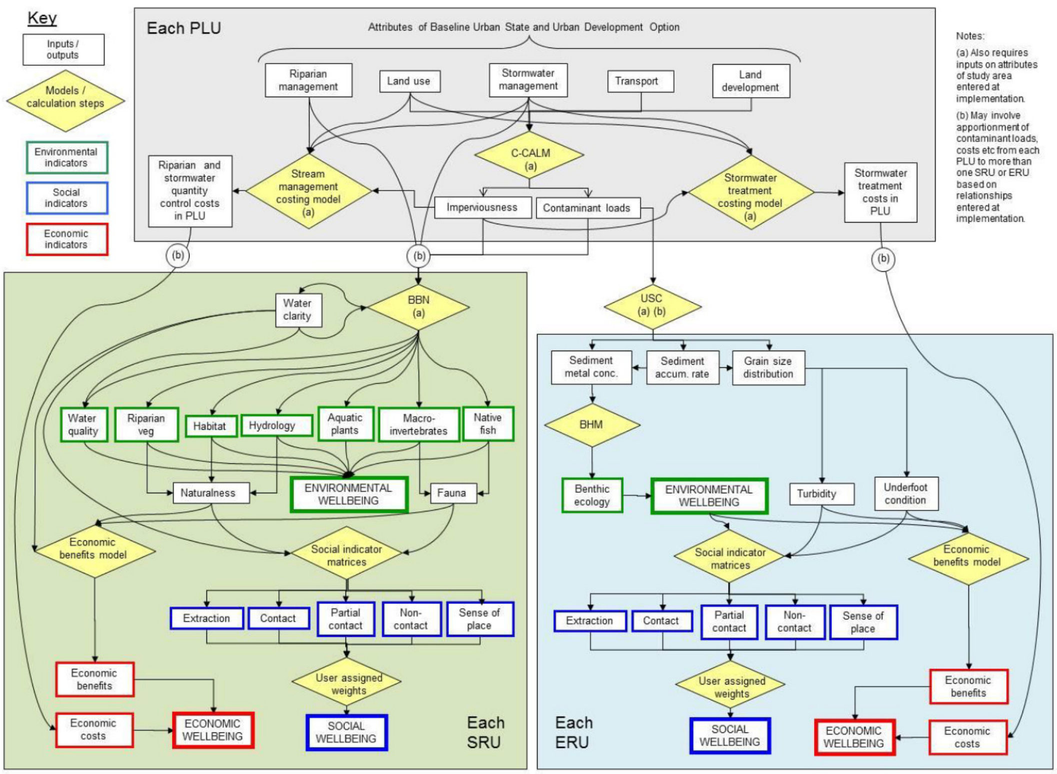


Figure 10-1 Structure of pilot DSS (Moores et al., 2013, reproduced with permission)

The DSS makes a quantitative assessment of the effects of any given stormwater management scenario. As way of example, focusing on the economic indicators:

- the economic costs indicator is calculated as the lifecycle costs (capital and operational/maintenance) of the stormwater management approach adopted in the scenario; and
- the economic benefits indicator is calculated as the change in regional Willingness To Pay (WTP) associated with a change in stormwater-related attributes of the receiving environment. Refer to Section 10.2.4.4 for details of the WTP survey carried out by Cawthron Institute (Batstone and Sinner 2010). The economic benefits indicator is not aggregated to the regional level and is expressed in $ per household per year and then normalized as described below.

Both indicators are expressed in monetary terms. These dollar values are then normalised in order to convert them to an indicator level (in the range 1-5). These indicator levels are reported using the 'traffic lights' system. The highest level is coloured green and the lowest level is coloured red (refer to Figure 10 -2). Comparison of pre and post development indicator scores helps gauge the relative outcomes under alternative future urban development scenarios.

This tool is able to clearly demonstrate the correlation between different stormwater management scenarios and effects on the receiving environment water and sediment quality and ecosystem health.

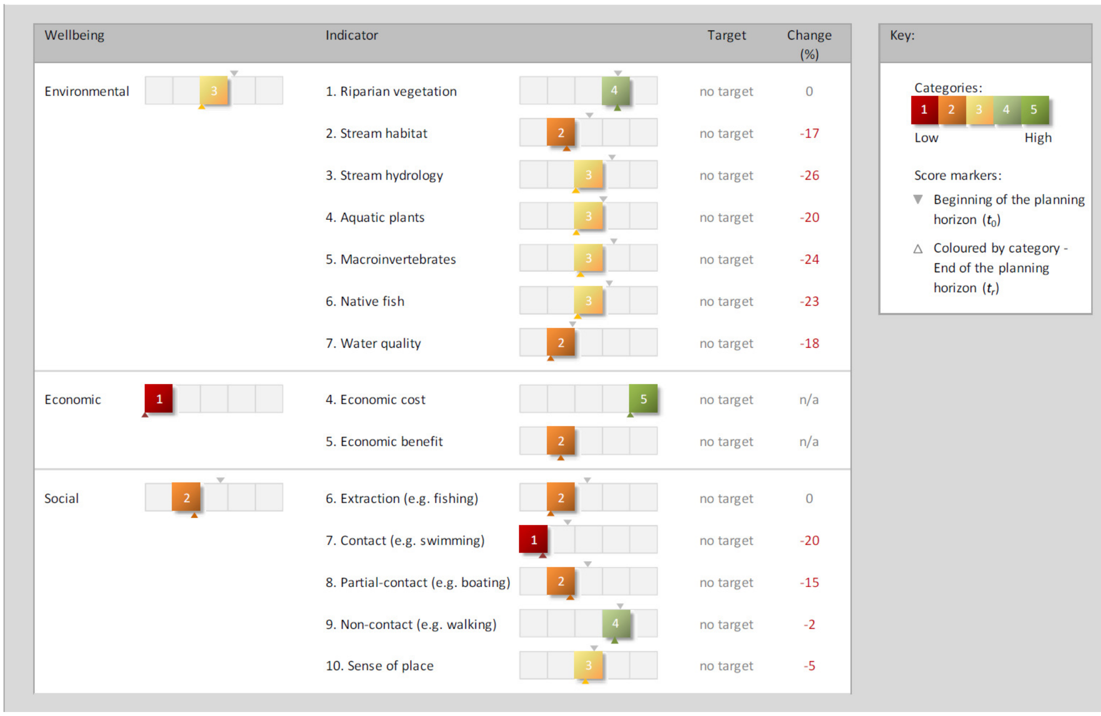


Figure 10-2 Example of indicator levels in DSS tool (Moores et al., 2013, reproduced with permission)

10.2.2 Total Economic Value

A recent report completed for the Auckland Council (Rohani 2013) has recommended the use of a Total Economic Value (TEV) framework for estimating the value of Auckland's freshwater resources.

As depicted in Figure 10-3, the Total Economic Value is made up of a series of different types of values.

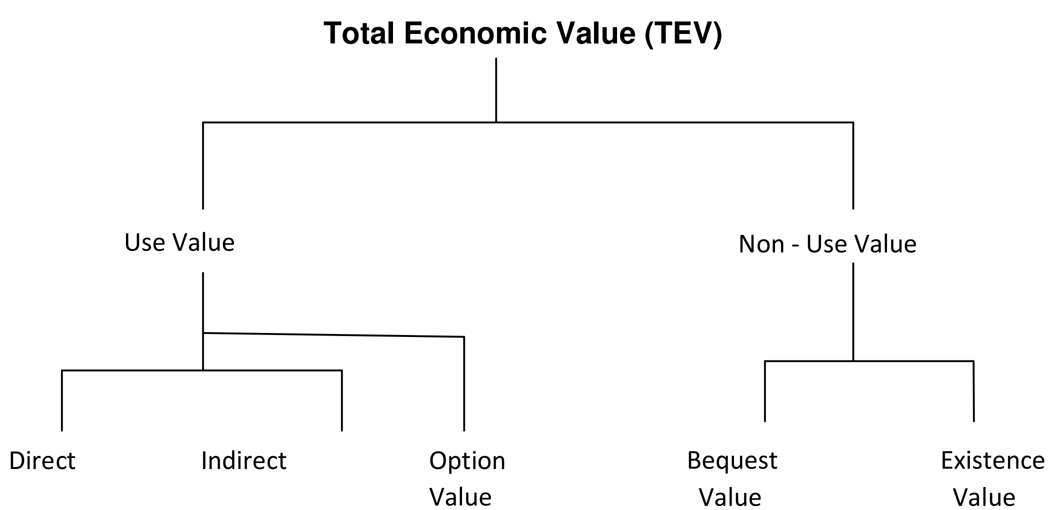


Figure 10-3 Total Economic Value Framework (adapted from Rohani 2013)

Use value derives from actual use of the water resource. Use values can be further broken down into direct, indirect and option values:

- Direct – examples are irrigation, industrial/municipal supply, energy resource, transport/navigation, recreation and amenity.
- Indirect – examples are waste treatment, wildlife harvesting, nutrient cycling, climate regulation and ecosystem support.
- Option – potential future uses (direct or indirect) e.g. pharmaceuticals.

Non-Use values are independent of the individual's present use of the resource and are described as:

- Bequest – the value arising from the desire to bequeath certain resources to one's heirs or future generations, for example, habitat preservation.
- Existence – the value from knowing that a particular environmental asset exists, for example, endangered species, habitat and biodiversity.

Some of these components are easier to measure than others. *Direct use values* are generally the most straightforward to measure because they are observable quantities of products consumed as well as market prices that can be used to determine economic value. Recreational use can also be measured by observing the number of visits and the characteristics of visitors and sites.

Indirect use values are more difficult to measure as they are not usually traded in marketplaces and therefore have no associated prices.

Option values and *non-use values* are the most difficult to measure because these are not reflected in observable behaviour. These values are estimated by using surveys that ask people a series of questions about their willingness to pay for ecosystem services they value but do not use.

10.2.3 Mauri Model

Mauri is a measure of the vitality of something living or the capacity to support life in air, water, earth, and ecosystems (Morgan 2007). The model measures mauri in four dimensions – environmental wellbeing (taiao mauri), cultural wellbeing (hapu mauri), social wellbeing (community mauri) and economic wellbeing (whanau mauri) (refer to Table 10-2). Indicators are then chosen that represent the impacts upon mauri for each dimension. The impact upon indicators is measured using the **mauriOmeter**, (refer to Figure 10-4)**.** It gives the user the ability to assess several different potential options/scenarios and assess the relative outcomes and their impacts over time (www.mauriometer.com, August 2013).

Table 10-2 'Mauri Model' Sustainability Indicators (adapted from Morgan 2007)

Mauri of the Ecosystems Equivalent to Environmental well being	**Mauri of the Family** Equivalent to Economic well being	**Mauri of the Community** Equivalent to Social well being	**Mauri of the Hapu (band)** Equivalent to Cultural well being
State of the ecosystem reflects it's mauri	Affordability of particular design choices	Participation, implementation, buy-in to strategy	protocols, practices, places, relationships, power
watershed and aspects of hydrological cycle	effective use of resources during construction	promote public health, safety and well-being	authority, responsibility, guardianship, expertise
springs, rain, rivers, lakes, swamps, estuaries, ocean	return from commercial activities on-site	education, recreation, leisure associated with ecosystem	knowledge, action, resources, food sources
physical health and proliferation of flora and fauna	integrated employment opportunities	reducing reliance and impact on infrastructure	gathering places, forests, lakes, mountains
land, forest, birds and insects, assimilative processes	impact on family health and well being	employment and public access to food resources	reserves, prohibitions, cycles, phenomena

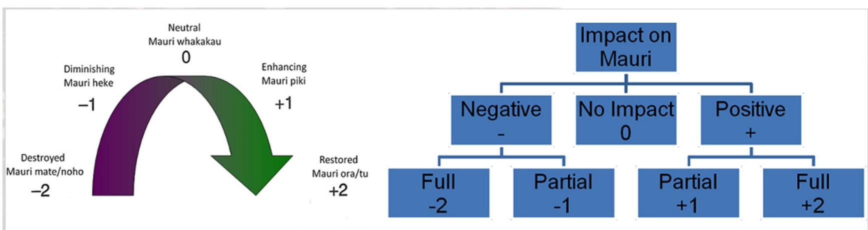


Figure 10-4 mauriOmeter (www.mauriometer.com, August 2013, reproduced with permission).

As shown above, the 'Mauri Model' assesses an option based on whether it is identified as restoring, enhancing, neutral, diminishing or destroying the mauri of the context being considered. The various indicators are given a raw score between -2 and +2 and weightings are assigned to each indicator. The product of the scores times the weightings give a final score for each indicator. The individual scores are then summed up to compare scores for each proposal to provide a mechanism to choose between alternatives.

10.2.4 Monetary Valuation Studies

The following international, national and Auckland sources have been used to quantify the benefits of the water environment:

- 'The Value of the World's Ecosystem Services and Natural Capital' (Costanza et al 1997).
- 'Assessing the Value of New Zealand's Biodiversity' (Patterson and Cole 1999).
- 'Auckland Regional Stormwater Project: An Economic View' (Auckland Regional Council TP3 1991).
- Willingness to pay - Auckland and International studies.

10.2.4.1 ‘The Value of the World’s Ecosystem Services and Natural Capital’

In a report to the European Commission in 2000 on ‘An Assessment of the Socio-Economic Costs & Benefits of Integrated Coastal Zone Management’ (Firn Crichton Roberts Ltd et al. 2000), the calculations of environmental services value within 21 European demonstration areas were based on the work of Costanza et al (1997). Costanza estimated the value of a wide range of biomes, given below in annual €K/km^2 (recognised as the second most highly-cited analytical paper in the history of environmental studies (The Royal Society of New Zealand 2011)):

- estuarine waters – 2,400
- swamps and floodplains – 2,000
- tidal marshes – 1,000
- lakes and rivers – 900
- open ocean – 26
- cropland – 10
- urban areas – 0

Using these values Costanza et al (1997) estimated the economic value of global ecosystem services at US$33 trillion per year, nearly double the global GNP of US$18 trillion per year, making clear the magnitude of both the contribution that ecosystems make to human wellbeing and the extent to which the environment is latent in current economic measurement. Citations for Costanza are both in support and critical. While the figure of $33T is widely cited, it is also widely criticised for example in using marginal values to estimate total value. However what the Costanza paper did achieve is raising the recognition and discussion on environmental goods and services and the real scale of their potential value.

10.2.4.2 Assessing the Value of New Zealand’s Biodiversity

The report by Patterson and Cole (1999), ‘Assessing the Value of New Zealand’s Biodiversity’ estimated the total economic value from New Zealand’s biodiversity for the year 1994 as $44 billion, consisting of the sum of direct use value, indirect use value and passive value of land-based biodiversity. The study broke ecosystems down into different types. For instance, the direct and indirect annual value of wetlands was estimated at $34,000 per hectare and estuarine areas at $40,000 per hectare. This 1999 NZ$40,000 per hectare is equivalent to 2013 NZ$ $57,000 per hectare. Auckland has 70km^2 of brackish estuarine waters which gives a value of 2013 NZ $400,000,000 per annum.

10.2.4.3 ‘Auckland Regional Stormwater Project: An Economic View’

The first study in Auckland on valuing a wide range of social and environmental variables was carried out in 1991, called the ‘Auckland Regional Stormwater Project: An Economic View’ (Auckland Regional Council TP3 1991). The project estimated the total benefits being derived from the 1991 level of water quality in the Auckland harbours as $442 million annually (CPI adjusted to 2013 NZ$700 million), refer Table 10-3. Of interest is that this annual $442M equates to approximately $300 per head of population, or $850 per household (at 2.8 persons per household). While it is recognised that these benefits arise from more than just stormwater management, such as wastewater treatment, management of spills, riparian and bush plantings, it is nevertheless a significant annual benefit.

Table 10-3 Annual Value of Benefits (Auckland Regional Council TP3 1991)

Benefits		**Annual Value ($million)**
Amenity	Harbour	222
Commerce	Tourism	11
	Fishing	11
Recreation	Beach	9
	Boating	32
	Fishing	1
	Shellfish Gathering	8
	Watersports	7
Flow-on[(1)]		62
Intangibles[(2)]		79
TOTAL		**442**

Notes to Table: (as cited in Auckland Regional Council TP3 1991, Table 2.11)
(1) The flow on effects are additional benefits which derive from the primary impacts (e.g. the fishing and tourist industry spend money on supplies and other expenses). Those who earn wages and make profits from these activities spend them and in so doing generate further economic activity. These impacts can be taken into account by the use of multipliers. The report used the work of Butcher (1985) to derive an appropriate multiplier of 2.0. On this basis it was assumed that each dollar of benefit from fishing, tourism and commercial recreation generates another dollar in indirect effects (ARC Report p23).
(2) Intangible benefits are those that are not readily quantitatively reflected in economic assessments, such as intrinsic, aesthetic, cultural and spiritual values. The report used the work of Fisher and Raucher who found that intangible benefits ranged from 0.47 to 2.03 times the value of use benefits. Although their study was based only on recreational use, the same principle applies to other uses. On this basis the intangible benefits were taken using a multiplier of 1.0 on the combined value of commerce and recreational benefits of $79 million. Note that the use of the term "intangible" can be confusing in an environmental context. For example, the human happiness arising from knowing of the existence of a species of fish is intangible, but the fish themselves are a tangible object, as is the forests and streams they live in.

The study also estimated the 'future benefit loss from water quality deterioration.' If the present level of water quality were not maintained, it was assumed that deterioration would occur which would erode the present annual benefits. This potential loss of benefits can conversely be considered as future benefits which would arise from the maintenance of current water quality standards. The study assumed that in the absence of a stormwater project, pollution would increase at rates of between 0.5 percent and 1.5 percent annually over a planning period of twenty years, resulting in annual losses of the benefits of water quality. These falls would be cumulative and the total losses in benefits involved over the twenty year period were expressed as presented in Table 10-4.

Table 10-4 Future Benefits Loss from Water Quality Deterioration (Auckland Regional Council TP3 1991)

Future benefit loss from water quality deterioration (over a twenty year period with a discount rate of 10%)		
Pollution Increase rates	Present value ($m)	Annual equivalents ($m)
0.5%	$126	$15
1.0%	$257	$30
1.5%	$396	$47

The study then estimated the total benefits from maintaining current water quality as the summation of the following annual percentages:

- water quality deterioration – taken as the lower level of 0.5%.
- population growth of 1.7% - this population growth leading to a rise in demand for recreational/environmental services including the use of harbour and beaches.
- real income would grow at 1% - social valuation placed on environmental resources tends to rise over time with rising real incomes.

These cumulative percentages added up to a present value of over $800M, or an annual equivalent of $100M, CPI adjusted to 2013 NZ$160M per year.

10.2.4.4 Qualitative/Quantitative Surveys and Questionnaires

10.2.4.4.1 Willingness to Pay

This valuation method uses statistical techniques to infer a 'willingness to pay' for goods or services from survey questions asking a sample of respondents to make choices among alternative proposed policies.

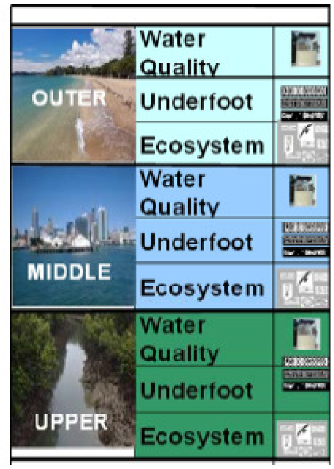
One of the more recent studies on valuing Auckland's coastal ecosystems was a report by the Cawthron Institute (Batstone and Sinner 2010). The paper describes the design and implementation of a 'choice experiment' to understand Aucklanders' preferences for environmental qualities associated with the effects of urban run-off on marine coastal environments. An unlabelled choice experiment was developed with three environmental quality attributes specified at three broad coastal categories. The three environmental qualities being; 1) ecological health, 2) water quality, and 3) underfoot conditions. The three broad coastal categories were; 1) outer coastal beaches, 2) middle harbour, and 3) upper harbour/estuary. These WTP survey results have been used in the NIWA DSS tool (Refer to Section 10.2.1)

The figure below summarises the results and shows some interesting trends. It is recommended that one focuses on the relative trends, rather than giving too much attention to the actual dollar values, given the inherent assumptions in estimating absolute willingness to pay values.

The relative annual willingness to pay indicates:

- greater willingness to pay in 'north Auckland', then 'central Auckland', last is 'south Auckland'.
- greater willingness to pay for the 'outer harbour' coastal beaches, next the 'upper harbour'/estuary, and then last is the 'inner/middle harbour'.
- water quality leads ecological health, then underfoot conditions in importance at beach locations.

The willingness to pay estimates by data collection location is presented in Figure 10-5. Keys to the terminology presented in the figure are:



Location (first letter):	OT = outer coastal beaches
	IN = inner/middle harbour
	UP = upper harbour
Environmental quality attribute (middle letter)	E = Ecosystem
	W = Water quality
	U = Underfoot
Level of environmental quality attribute (last letter)	M = medium
	H = high

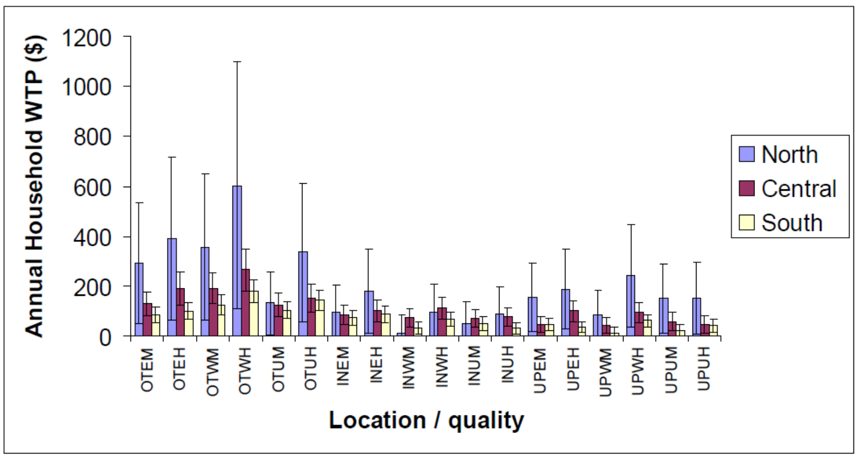


Figure 10-5 Annual Household Willingness to Pay (WTP) (Batstone and Sinner 2010)

Although the above 'annual household willingness to pay' values offer a wide range, from $50 to $1,000, it nevertheless is similar to those researched elsewhere. The paper gave the findings from a choice experiment for improvements in water quality on Sweden's west coast at annual 2003 NZ$130 to $300 (Eggert and Olsson 2003, as cited in Batstone and Sinner 2010). The paper also notes earlier international studies by others (from six different sources) which provide varying estimates of the value that beach users place on water quality changes that typically range from NZ$4 to NZ$39 per person per year (at 2.5 persons per household, equates to NZ$10 to NZ$100 per household per year).

These willingness to pay values are also consistent with another study carried out for the Auckland Regional Council in 2003 (Lincoln University 2003, Auckland Council 2006). The report used the 'choice modelling' technique to measure the monetary value of environmental changes and to identify mitigation packages that the community considers are adequate to offset specified environmental damages. In 'choice modelling' people are presented with a set of options and are asked to report their single preferred option from that set. This study indicated that an average household would pay $109 per year for the prevention of stream degradation, or $55 per year for the improvement of degraded streams.

A summary of the above willingness to pay values is presented in Table 10-5.

Table 10-5 Summary of Willingness to Pay

Study	Range (Annual NZ$ per household)
Auckland's Coastal Ecosystems (Batstone and Sinner 2010) - coastal	Total range $50 to $1,000 Generally $50 to $100
Sweden's West Coast (2003) (as cited in Batstone and Sinner 2010) – coastal	$130 to $300
Other International Studies (as cited in Batstone and Sinner 2010) – coastal	$10 to $100
Auckland's for prevention of stream degradation (Lincoln University 2003) - streams	$109

10.2.4.4.2 Questionnaires

Questionnaires are another means of collecting information on the value the community places on the natural environment. An example is an Auckland Council questionnaire survey sent out during the engagement phase of the Hibiscus and Bays Area Plan in 2012. The questionnaire put forward a number of questions and asked people to rank the level of importance from 1 (not important) to 4 (very important). In response to question number 13, 'Items of importance to submitters', the highest ranking item of importance was 'Natural Environment' with an average ranking of 3.55, next was 'Recreation facilities, parks and reserves' at 3.52, and third 'Beaches' at 3.46 (refer last column in Table 10-6). The 'average ranking' was calculated by first summing the ranking number (1 to 4) times it's respective number of submitters (to give the 'Score' in Table 10-6), then dividing the score by the total number of submitters. Of interest is that the 'Natural Environment' item was ranked a 3 or a 4 by all submitters.

Table 10-6 Questionnaire Responses to 'Items of importance' (adapted from Auckland Council 2013d)

Question 13. Items of importance to submitters. Ranked 1 (not important) to 4 (very important)								
Item of Importance	**1**	**2**	**3**	**4**	**N/A**	**Total**	**Score**	**Average Ranking**
Natural Environment	0	0	15	96	10	121	429	3.55
Recreation facilities, parks and reserves	4	3	21	96	6	130	457	3.52
Beaches	4	3	12	100	10	129	446	3.46
Sense of place etc.	2	9	13	96	11	131	443	3.38
Air quality	0	5	18	90	15	128	424	3.31
Quality school/tertiary education	7	0	21	72	12	112	358	3.20
Public transport	6	13	24	77	9	129	412	3.19
Walkways/cycleways	4	15	26	73	13	131	404	3.08
Thriving economy	8	11	33	66	11	129	393	3.05
Local employment opportunities	4	11	38	64	13	130	396	3.05
Healthcare services/facilities	4	9	37	64	14	128	389	3.04
Affordability of housing/variety of housing types	7	19	35	54	13	128	366	2.86
Water sports, boating, fishing	13	24	22	60	11	130	367	2.82
Rural Environment	13	15	28	58	16	130	359	2.76

While there is certainly debate and variation in the economic valuations of our water environment, there is no doubt that they do have a real value. This has been supported in the Auckland context where legacy councils have actively consulted with their communities through the then Long – Term Council Community Plan (LTCCP) process about the costs and associated benefits of varying levels of expenditure on network improvements and the associated bathing beach and other amenity improvements that would result. In both cases, these ‘real world’ communities opted for higher levels of expenditure in order to enjoy the higher levels of environmental and amenity/recreation/spiritual benefits that would result.

11.0 Cost Benefit Analysis Case Studies

This section provides additional information on the South East Queensland Business Case (Water by Design 2010) and work by the U.S. Environmental Protection Agency (Braden and Ando 2011) summarised in Section 3.3 of the main report.

11.1 South East Queensland Business Case

The report 'A Business Case for Best Practice Urban Stormwater Management' was developed by the Water by Design program of the South East Queensland Healthy Waterways Partnership (Water by Design 2010) to determine if the benefits of applying WSD practices to achieve best practice stormwater management are likely to outweigh the costs for typical development types.

A simple cost-benefit framework was developed and populated with the likely costs and benefits of using WSD practices to meet the proposed design objectives for typical low density residential (400 to 700m^2 lots), medium to high density residential, and commercial and industrial developments. The frameworks brought together both quantitative and qualitative values of likely benefits and costs to assist in approximating the net benefits.

The stormwater management design objectives for the South East Queensland waterways are:

- Stormwater quality: limit quantity (loads) of stormwater pollutants discharged into the receiving waters
- Frequent flow objective: capturing the initial portion of runoff from impervious areas to protect in-stream ecosystems from the effects of increased runoff frequency
- Waterway stability objective: limit post-development peak 1-year ARI event discharging within the receiving waterway to the pre-development peak 1-year ARI to prevent in-stream erosion downstream of the urban development.

Data was gathered through a literature review; semi-structured interviews with industry stakeholders; and case study assessments of six different development types in Brisbane, Mackay, Townsville and Cairns.

The literature review found that key benefits of best practice urban stormwater management are likely to include (Water by Design 2010):

- Reduced pollutants loads discharged to waterways relative to unmitigated urban development, which is estimated to be a potential annual saving of $515 per kilogram of TN removed ($AUD, 2010).
- Reduced need for rehabilitation and maintenance of downstream water environments, which can range from $250 to $3,500 per metre of stream per annum ($AUD, 2010).
- Premiums on land values due to enhanced amenity values and local and regional water quality, which have been estimated to range from 0.25 to 1.0%.
- Educational benefits.

Best practice urban stormwater management was also recognised as assisting to preserve and enhance waterway-based recreation, current commercial values of water ways such as tourism and commercial fishing, and important non-market values such as intrinsic value of aquatic ecosystems.

The conclusion regarding the relative magnitude of likely costs and benefits was (Water by Design 2010):

- Considering all the costs and all the potential benefits of applying WSD to achieve the proposed stormwater management design objectives it is concluded that the **benefits are *likely* to outweigh the costs for low-density residential development in Queensland.**
- The estimated acquisition costs of applying WSD within low-density residential developments equate to an average cost of approximately $3,400 per dwelling. This value is equivalent to 0.7% of a house and land package worth $480,000. This cost will usually be passed onto the homeowner, so it should not significantly impact the profitability of development.
- The estimated annual maintenance costs are an average of $35/year. Where councils undertake the maintenance of WSD assets in public areas, this cost is likely to be passed onto the homeowner via rates.
- Considering just the quantifiable benefits, on average, the value of TN reduction is worth more than the total life cycle cost of WSD measures. The potentially avoided waterway rehabilitation costs (expressed as life cycle) are worth around 67% of the life cycle cost of WSD and the potential property premiums are worth around 90% of the acquisition cost of WSD. Considering the quantifiable benefits in a lumped group, *the potential quantifiable benefits are likely to outweigh the costs.*

Note: all values are in $AUD (2010)

Some important notes on the above conclusions are:

It should be noted that some of the Queensland objectives and designs are somewhat different to those for Auckland. For example, Queensland's objectives do not appear to have Auckland's focus on reducing runoff volumes and the Queensland's wetland's focus more on nutrient removal which is not a target contaminant in Auckland. Despite these differences the case study is still relevant as a demonstration of the type of cost-benefit study that can be carried out and some of the benefits used are applicable to Auckland. Examples of the types of benefits that are common to both the Queensland study and Auckland are the potentially avoided costs associated with downstream waterway rehabilitation and maintenance; potential increased property values and potentially avoided development costs.

The majority of the residential scenarios were in greenfield developments with precinct-scale bioretention 'pods' serving multiple lots, hence reducing the cost of bioretention devices per lot. To meet the Queensland stormwater objectives the bioretention surface area varies from 1 to 1.5% of the site area, significantly less than the Auckland SMAF flow controls that require bioretention surface areas of approximately 6% of the impervious area.

Used marginal costs relative to base case. For example, the net cost of bioretention systems calculated for the WSD case is the cost of the bioretention system less the cost of typical landscaping.

Gross bioretention costs were estimated at $480/m^2, less landscaping costs of $66/m^2, giving a net acquisition cost of $414/m^2. The bioretention device had a minimum 400mm depth of planting media. A gross annual maintenance cost for the first 2 years was $18/m^2/yr (a net annual maintenance of $15/m^2/yr) with ongoing (after 2 years) gross maintenance costs of $6/m^2/yr (for a net annual maintenance of $3/m^2/yr).

Gross detention storage volumes were estimated at $50/m^3 acquisition costs and $3/m^3/year annual maintenance for above-ground and $360/m^3 acquisition costs and $1.20/m^3/year annual maintenance for below ground. Net costs were only estimated for the above-ground storage subtracting landscaping costs, giving net acquisition cost of $30/m^3 and annual maintenance of $1.20/m^3/yr.

Large variation in acquisition costs. Acquisition costs varied from $500 per dwelling for multi-units in large complexes to between $1,900 to $4,800 per household for detached houses.

11.2 USA Environmental Protection Agency

11.2.1 Water Quality Benefits (based on Willingness to Pay)

Based on survey samples drawn in North Carolina and Colorado, Marge et al., 2000 (as cited in Braden and Ando 2011) concluded that households in these States would pay an annual average of $22.40 for a 1% improvement in generic water quality. Viscusi et al., (as cited in Braden and Ando 2011) expanded the survey to a national sample and found nearly identical results, national mean annual household willingness to pay $23.17. In $US 2008, this equates to $30.70/year for a 1% change in water quality.

The EPA (as cited in Braden and Ando 2011) determined that construction phase measures achieve 0.7% average reduction in suspended sediment concentrations. Proportionally adjusting the WTP estimate derived from Viscusi et al produces an estimate of $21.50/year per household.

In 2000, there were 105.5 million households in U.S. Assuming 25% of U.S. households live near affected surface waters, and that their average value of improvements is 10% above the national average, results in an annual value of improvements of nearly $624 million.

Unlike construction-phase retrofit technologies, LID measures have enduring rather than temporary effects on water quality. With LID, a fraction of annual benefits would recur year after year. An on-going national benefit of only $23million/year (less than 4% of the initial benefit) for 20 years , discounted at 3% real interest rate, would be sufficient to close the gap between the estimated WTP ($624 million) EPA's estimated cost of $959 million/year (as cited in Braden and Ando, 2011).

11.2.2 Flood Reduction and Infrastructure Benefits

A case study was done by Johnston et al., 2004 (as cited in Braden and Ando 2011) for a rapidly growing area west of Chicago, comparing conventional and LID development. The differences in flooded areas were mapped for both development scenarios. The change in property values for homes that would face reduced flooding in the LID scenario was computed. Estimated flood benefits ranged from 2 to 5% of the property value. These benefits result from increase in property values when homes are less prone to flooding or no longer need to buy flood insurances.

Some of the benefits also accrue to homeowners through higher market value of LID homes and to developers through greater profits. Consumers are willing to pay a premium for homes that benefit from neighbourhood water features such as wetlands that are part of stormwater management.

For the conventional scenario, the size and cost of culverts that would be required to convey the respective storms were calculated. The savings were then attributed to each developed acre.

The estimated flood benefits were $110 to $158 per developed acre and infrastructure cost savings were $340 per developed acre ($US 2000). The total estimated benefits were $450 to $498 per developed acre. Adjusted to 2008 dollars, the total benefits are $563 to $623 per developed acre.

To convert the above to annual figures, a 20-year annualisation period and a 3% inflation-free interest rate was used, resulting in annualized benefits of approximately $40/developed acre/year. EPA assumed an average of 850,000 acres developed each year, which equates to a nationwide flood reduction and infrastructure downsizing benefits of LID measures in the order of $34 million/year ($US 2008).

11.2.3 Combined Sewer Overflow (CSOs)

In areas with combined sewers, LID measures can reduce the need for costly storage and treatment of CSOs. Thurston et al. (as cited in Braden and Ando 2011) found that LID measures would cost less than half as much as additional CSO storage capacity in a basin in Cincinnati.

Montalto et al., (as cited in Braden and Ando 2011) undertook a modelling study of an area in Brooklyn, New York which showed that under various conditions, LID measures combined with a basic level of storage can be cheaper than building larger storage facilities. Predicted savings however depend on the desired level of control and on the incremental costs of additional CSO storage capacity.