Structural Stormwater Quality BMP Cost / Size Relationship Information From the Literature

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INTRODUCTION

This document summarizes cost-related information for structural stormwater quality best management practices (BMPs) that was found in the literature. This information was reviewed as part of the CRC for Catchment Hydrology's investigation into the estimation of life cycle costs for structural stormwater quality BMPs. Some of this information is being used (along with individual BMP costing data from all Australian States) to develop a life cycle costing module in the CRC's MUSIC model.

This information has been summarized to provide guidance to urban stormwater managers who are seeking costing information:

- while the MUSIC life cycle costing module is being developed during 2003-05; or
- to help choose inputs to the MUSIC life cycle costing module (i.e. users of this module are able to manually enter figures into any cost element of the BMP's life cycle analysis, if they do not wish to use MUSIC's estimates).

Basic BMP cost / size relationships from the literature should be used with caution. The CRC's work involving BMP costing has found a very high degree of variability in most cost elements. Despite this variability, very few cost-related studies report confidence intervals associated with their cost estimates. The life cycle costing module in MUSIC addresses this deficiency by allowing users to generate upper and lower estimates for each cost element in the life cycle analysis.

The dollar values quoted in this report have *not* been adjusted for inflation. For example, if the referenced source of a cost estimate is "CRC (2002)", the dollar values are in 2002 Australian dollars. At the time of writing, 2% is a suggested annual inflation rate that is relevant to these types of assets.

GROSS POLLUTANT TRAPS (GPTs)

An in-ground GPT supplier undertook a survey of its units in NSW from October 1997 to September 2000. The study looked at 334 maintenance events involving the removal of 1,345 tonnes of gross pollutants (in total). This survey found that typical annual maintenance costs ranged from \$0.13/kg (in 2001 dollars) for larger units to \$0.28/kg for smaller units. This range equates to approximately \$0.17/ha/day to \$0.78/ha/day.

The NSW EPA (2002) developed a spreadsheet that lists approximate unit prices (i.e. capital costs) for a wide range of proprietary GPTs. This spreadsheet also provides some information on typical maintenance costs associated with these units. A summary of these costs is provided below:

- Rocla Downstream defender: ~$12,000 to $36,000 capital (all costs in 2000 dollars), with maintenance cost of ~$20 per ha per month (suction cleaning).
- Stream Guard - catch basin insert: ~$290 capital plus ~$200 p.a. maintenance.
- Stream Guard - passive skimmer: ~$60 capital plus ~$200 p.a. maintenance.
- Enviropod - 100-500 micron screen: ~$440-620 capital plus ~$200 p.a. maintenance.
- Ecosol RSF100: ~$430-903 capital plus ~$200 p.a. maintenance.
- CSR Humes Humceptor: ~$10,000-50,000 capital plus a maintenance cost of ~$20 per ha per month (suction cleaning).
- Rocla Cleansall: ~$20,000-150,000 capital plus up to ~$14,400 p.a. maintenance.
- Ecosol RSF 1000: ~$4,000-12,000 capital plus up to ~$12 per ha per month for maintenance.
- Baramy: ~$15,000-40,000 capital plus up to ~$12 per ha per month for maintenance.
- CSR Humegard: ~$18,000-51,000 capital plus up to ~$14,400 p.a. maintenance.[1]

WBM Oceanics has undertaken a review of the capital costs, operating costs and performance of a range of proprietary stormwater treatment measures for the NSW Stormwater Trust. This material is yet to be published, but maintenance costs associated with the collection and disposal of wastes collected by various gross pollutant traps are reported within a broad range of $160 to $700 per cubic metre of waste (S. Barter, pers. comm., 2004).

In addition to this cost range, WBM have estimated a $/yr figure for typical BMP inspection costs (i.e. ~$120 - 720/yr) and an annual administration fee ($10 - 100/yr). Note these cost estimates are based on unit rates and predictions of expended time, not real expenditure.

The WBM estimates are based on summarised costing data from NSW Councils in the late 1990s and also estimates of what maintenance *should* be done and what it should cost (based on unit rates). It makes no allowance for the time value of money, whether GST is (or isn't) included, and does not consider parts of the life cycle (e.g. defining the need for the BMP, renewal / adaptation costs, decommissioning).

Hornsby Shire Council (2002) produced a "Catchment Remediation Capital Works Program: Annual Performance Report 2001-02" which includes some costing information for 2001-02:

- Trash racks (n = 17): average capital cost ≈ $966/ha; average annual maintenance cost ≈ $2,346; and average annual maintenance cost per ha ≈ $39.
- Large trash baskets (0.5 m^3 capacity) (n = 9): average capital cost ≈ $2,117/ha; average annual maintenance cost ≈ $708; and average annual maintenance cost per ha ≈ $42.
- Proprietary in-ground devices (n = 19), not including SEPTs: average capital cost ≈ $6,122/ha; average annual maintenance cost ≈ $765; and average annual maintenance cost per ha ≈ $156.

[1] Note that true life cycle costing in accordance with the relevant Australian Standard (Standards Australia, 1999) considers more than just construction/purchase cost and typical annual maintenance cost. For more information see Taylor (2003). Also, these approximate costs will vary with time and location. For up-to-date costs of proprietary units, contact the GPT supplier.

Based on a limited data set from Brisbane, Weber (2001 and 2002) reported the following cost estimates:

- Side entry pit traps (SEPTs): The typical capital cost ≈ \$1,700 – \$2,900/ha (of area treated).
- Trash racks (no sediment capture): The typical annual maintenance cost ≈ 30% of construction cost. Also, typical construction cost ≈ \$20,000 and typical annual maintenance cost ≈ \$6,000.
- Trash racks (with sediment capture): The typical annual maintenance cost ≈ 6% of construction cost. Also, typical construction cost ≈ \$120,000 and typical annual maintenance cost ≈ \$7,600.
- Floating litter traps: The typical annual maintenance cost ≈ 7% of construction cost. Also typical construction cost ≈ \$50,000 and typical annual maintenance cost ≈ \$3,600.
- Open GPTs[2]: The typical annual maintenance cost ≈ 3% of construction cost. Also, typical construction cost ≈ \$350,000 and typical annual maintenance cost ≈ \$10,000.
- In-ground GPTs: The typical annual maintenance cost ≈ 10% of construction cost. Also, typical construction cost ≈ \$200,000 and typical annual maintenance cost ≈ \$20,000.

Walsh (2001) reported that the typical capital cost in Melbourne for vortex type in-ground GPTs that are operated by local government authorities was \$100,000 per m^3/sec (when the flow is at its peak treatment rate).

A 'rule of thumb' for BMP costing in Penrith / Blacktown (based on 10 years experience): Big GPTs ≈ \$10,000 p.a. for typical maintenance (Hunter, 2003).

Information from Frankston City Council (Victoria):

- SEPTs cost approximately \$200 (each) and ~\$15 (each) to maintain approximately 12 times a year. Assume life span ≈ 10 years.
- CDS maintenance typically cost ~\$1,000 per clean-out, and is required ~4 times a year.

A study by the NSW Department of Public Works and Services (2001) assumed typical annual maintenance costs for GPTs (e.g. CDS, Ecosol, Rocla, etc.) as being ~ 7% of capital cost (the rationale for this figure is not explained in the report). The study also estimated typical annual maintenance costs for nine types of GPTs (probably based on the '7% relationship'):

- CDS units average ≈ \$10,365 (no details of BMP size were provided).
- Ecosol units average ≈ \$13,059 (no details of BMP size were provided).
- CSR Humes units average ≈ \$14,492 (no details of BMP size were provided).

Lloyd *et al.* (2002) developed some BMP size / cost relationships for "litter and sediment traps" (combined):

- Construction cost (\$) ≈ 13,703 x (Catchment area in ha)$^{0.5904}$.
- Annual maintenance cost (\$) ≈ 311.67 x (annual volume of material removed from the trap in $m^3)^{0.8717}$.

Taylor (2005) used Australian GPT costing data to estimate that for GPTs *when considered as a group*, the:

- Cost of defining the need for the BMP[3] (N) ≈ 4.8% of total construction (TC) cost.

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[2] That is, a sediment basin with a trash rack.
[3] This is part of the BMP's life cycle cost (for an explanation, see Taylor, 2003).

- Total design cost (DC) ≈ 11% of TC.
- Total construction cost (TC) ≈ 94% of total acquisition cost (TAC), where TAC ≈ N + DC +TC.
- Typical annual maintenance costs (TAM) ≈ 7.6% of total acquisition cost (TAC).
- Renewal / Adaptation costs ≈ 0.71% of total acquisition cost (per annum).[4]
- Decommissioning costs ≈ 16% of total acquisition cost.

Taylor (2005) also used GPT costing data from all six Australian States to estimate various BMP size / cost relationships for in-ground GPTs, open GPTs (i.e. a sediment basin with a trash rack), trash racks and litter baskets, release nets, side entry pit traps, and floating trash racks and booms. These relationships have been built into the life cycle costing module in the CRC's MUSIC model and are documented in the User Manual for Version 3 of MUSIC. Estimates and algorithms address:

- Total acquisition cost as a function of the GPT's catchment area or total volume of the GPT when it is operating at full capacity (i.e. the volume of stormwater and trapped pollutants in the unit).
- Typical annual maintenance cost as a function of average annual volume of removed material or the GPT's catchment area.
- Renewal / Adaptation cost and renewal period as a function of total acquisition cost.
- Decommissioning cost as a function of total acquisition cost.
- Life cycle of various GPT types.

CONSTRUCTED WETLANDS

Leinster (2004) reported the following construction costs associated with wetlands in greenfield developments within South East Queensland:

- Small-scale wetland with an inlet pond, macrophyte zone, bypass weir and channel:
  - Macrophyte zone: 850m^2 (in area).
  - Inlet pond: 85m^2.
  - Total area: 935m^2.
  - Construction and planting cost: \$88,000 - \$93,000 (unit cost: \$90 - \$100/m^2).
- Larger-scale wetland to treat recirculated lake water:
  - Macrophyte zone: 3,500m^2 (in area).
  - Construction and planting cost: \$227,500 (unit cost: \$65/m^2).

The Centre for Watershed Protection (CWP, 1998), Weber (2001) and US EPA (2001) reported annual maintenance cost ≈ 2% of construction cost.

A 'rule of thumb' for wetland costing in Penrith / Blacktown (based on 10 years experience): ~\$500,000 per ha of surface area for design and construction cost, ~\$10,000 per ha (p.a.) for routine maintenance in the first 2 years (i.e. ~2% of design and construction cost, or ~1.96% of total acquisition cost) then ~\$5,000 per ha p.a. for routine maintenance (i.e. ~1% of design and construction cost, or ~0.98% of total acquisition cost), then major corrective maintenance very 10 years (~5% of construction cost). (Primary source: Geoff Hunter, 2003.)

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[4] This cost element involves infrequent maintenance events that involve an alteration to the design or replacement of BMP parts/re-construction (e.g. replacing a screen on a GPT, building a maintenance access track, or installing signage).

Weber (2002) reported typical construction cost ≈ \$500,000 each or ~\$3,400 – \$17,900/ha (of area treated) or ~\$730,000/ha (of wetland area). Also, typical annual maintenance cost ≈ \$8,200. This is information from Brisbane, based upon a very limited data set.

Walsh (2001) reported typical construction cost for greenfield wetlands in Melbourne ≈ \$120,000/ha of area treated (base cost).

Fletcher *et al.* (2003) suggested that the macrophyte zone needs to be replaced every 20-50 years at a cost of ~50% of the initial construction cost.

Melbourne Water (2003a) has a basic construction cost estimation model for large greenfield wetlands in Melbourne. It allows for typical site characteristics to be used as factors that determine overall construction cost. The cost relationships appear to be based on a limited data set (i.e. tender information for ~8 BMPs).

Lloyd *et al.* (2002) developed some BMP size / cost relationships for “wetlands and vegetated swales” (combined):

- Construction cost (\$) ≈ 343,913 x Ln(surface area of the BMP’s treatment area in ha) + 738,607.
- Annual *landscaping* maintenance cost (\$) ≈ 9,842.2 x (surface area of the BMP’s treatment area in ha)$^{0.4303}$.

A unit cost of \$75/m^2 (of wetland area) was used for the construction of a wetland with a 1 ha catchment during a desk-top water sensitive urban design project in the Snowy Monaro region (Lane, 2004). This rate did not include any costs associated with an up-stream gross pollutant trap which was included in the design (i.e. \$11,000 for the design and construction cost of a CDS unit), or construction work on the outlet of the wetland (estimated at \$5,000).

Taylor (2005) used Australian costing data to estimate, the:

- Cost of defining the BMP need (N) ≈ 2.3% of total construction (TC) cost (for all types of constructed wetlands).
- Total design cost (DC) ≈ 6.6% of TC (for all types of constructed wetlands).
- Total construction cost (TC) for greenfield wetlands ≈ 92% of total acquisition cost (TAC), where TAC ≈ N + DC +TC.
- Renewal / Adaptation cost ≈ 1.4% of total acquisition cost (per annum).
- Decommissioning costs ≈ 38% of total acquisition cost.

Taylor (2005) also used constructed wetland costing data from around Australia to estimate various BMP size / cost relationships. These relationships have been built into the life cycle costing module in the CRC’s MUSIC model and are documented in the User Manual for Version 3 of MUSIC. Estimates and algorithms address:

- Total acquisition cost as a function of the surface area of the BMP’s treatment zone.
- Typical annual maintenance cost as a function of the surface area of the BMP’s treatment zone.
- Renewal / Adaptation cost and renewal period (i.e. infrequent maintenance events that involve an alteration to the design or replacement of parts of the BMP) as a function of total acquisition cost.

- Decommissioning cost as a function of total acquisition cost.
- Life cycle.

INFILTRATION TRENCHES / SYSTEMS

Earthtech Engineering Pty Ltd (2003) in Melbourne used an estimate of ~$46-48 per linear metre for construction costs.

The Centre for Watershed Protection (CWP, 1998) and US EPA (2001) reported typical annual maintenance cost ≈ 5-20% of construction cost.

Fletcher *et al.* (2003) suggested that the construction cost of an infiltration trench is ~\$60-80/m^3 of trench (assuming the trench is 1 m wide and 1 m deep).

URS (2003) estimated the unit rate for the construction of a 1m wide, 1m deep infiltration trench in Sydney as $138/m. This cost estimate included: excavation, installation of geofabric liner, installation of perforated pipe, installation of gravel layer, installation of filter layer, application of top-soil, application of grass seed, application of fertiliser and watering.

Taylor (2005) used *limited* Australian costing data for infiltration systems to estimate, the:

- Renewal / Adaptation cost ≈ 4.1% of total acquisition cost (per annum).
- Decommissioning costs ≈ 35% of total acquisition cost.

Taylor (2005) also used infiltration system costing data from around Australia to estimate various BMP size / cost relationships. These relationships have been built into the life cycle costing module in the CRC's MUSIC model and are documented in the User Manual for Version 3 of MUSIC. Estimates and algorithms address:

- Total acquisition cost as a function of the surface area of the treatment zone.
- Typical annual maintenance cost as a function of the surface area of the treatment zone or total acquisition cost.
- Renewal / Adaptation cost and renewal period (i.e. infrequent maintenance events that involve an alteration to the design or replacement of parts of the BMP), as a function of total acquisition cost.
- Decommissioning cost as a function of total acquisition cost.
- Life cycle.

PERMEABLE PAVING

Costing information from Boral (2003) in NSW for five types of design:

- Permeable paving allowing infiltration: ~\$111/m^2.
- Permeable paving over sealed sub-grade, allowing water collection: ~\$119/m^2.
- Augmentation with permeable paving (i.e. mixing permeable with normal pavers): ~\$98/m^2.
- Permeable paving with asphalt: ~\$67/m^2.
- Permeable paving with concrete slab: ~\$90/m^2.

Fletcher *et al.* (2003) reported that the typical annual maintenance costs of permeable paving in California (when converted from US dollars) were approximately $9,700/ha.

URS (2003) estimated the cost of supplying permeable pavement blocks to be approximately $30 to $50/m^2 in Sydney. The total construction cost was estimated to be $98.4/m^2, which includes excavation and profiling, supply of blocks, installation of blocks, installation of geofabric liners, installation of gravel and installation of sand.

Boubli and Kassim (2003) reported costs associated with the Pioneer Street project in Sydney for 'permeable pavers' as being approximately $120/m^2 of paving. This estimate includes costs associated with supplying and placing the pavers.

BUFFER / FILTER STRIPS

Walsh (2001) reported:

- Turf buffer strips cost: ~$3.50/m^2 to construct in Melbourne.
- Sedge / Mulch buffer strips cost: ~$7.50/m^2 to construct in Melbourne.

URS (2003) reported that the construction cost of a typical grass buffer strip would be approximately $10 to $15/m^2 in the Sydney area (includes surface preparation, top-soiling and seeding with grasses). This cost estimate increases to approximately $20 to $50/m^2 if native grasses and shrubs are used as vegetation.

GRASSED / VEGETATED SWALES

Lloyd *et al.* (2002) suggested grassed swales cost ~$2.50/m^2/yr to maintain (but if residents do regular mowing there is less cost to local authorities). For vegetated swales the routine maintenance cost starts at ~$9/m^2/yr, then after ~5 years decreases to ~1.50/m^2/yr.

Fletcher *et al.* (2003) suggested the typical construction cost of grassed swales and buffer strips (based on advice from contractors) is ~4.50/m^2 which includes earthworks, labour and hydro-mulching. If rolled turf is used the cost is ~$9.50/m^2. The cost of a vegetated swale system using labour, earthworks and indigenous vegetation is between ~$15 to 20/m^2 (based on information from Indigenous Gardens Pty Ltd in Melbourne).

Bryant (2003) reported that it cost ~$120/m^2 for planting (excluding trees), excavation, soil, swale cross-overs, initial maintenance and irrigation of swales.

Leinster (2004) reported the construction cost associated with 'swale bioretention systems' in greenfield developments within South East Queensland as approximately $100 - 120/linear metre including vegetation. For this system the filter zone / swale base has a width of 1m and a swale top has a width of 3-4m.

Lloyd *et al.* (2002) developed some BMP size / cost relationships for "wetlands and vegetated swales" (combined):

- Construction cost ($) ≈ 343,913 x Ln(surface area of the BMP's treatment area in ha) + 738,607.

- Annual *landscaping* maintenance cost ($) ≈ 9,842.2 x (surface area of the BMP's treatment area in ha)$^{0.4303}$.

URS (2003) estimated unit rate construction costs for vegetated swales:

- $10/m^2 for grassed swales without sub-soil drainage.
- $18/m^2 if turf is used instead of grass seed (and no sub-soil drainage).
- An *additional* $10/m^2 is required for a sub-surface drain.

Beecham (2002) estimated vegetated swale maintenance costs for Sydney conditions as $3.13/m^2, based on the following unit rates: $1.62/100m^2 for mowing (required 2 – 3 times a year), $16.20/100m^2 for general grass care, $0.95/m^2 for litter removal, $0.65/m^2 for reseeding and fertilisation (1% of the total area is revegetated per year), and $1.35/m^2 for annual inspections and administration.

A unit cost of $100 per linear metre was used for the construction of a road-side grassed swale during a desk-top water sensitive urban design project in the Snowy Monaro region (Lane, 2004). Roadside swales are typically 3m wide.

See information below for "bioretention systems and swales" sourced from Taylor (2005).

BIORETENTION SYSTEMS

Leinster (2004) reported the following construction costs associated with bioretention systems in greenfield developments within South East Queensland:

- Bioretention systems greater than 100m^2 in area: $125 - 150/m^2 including vegetation.
- Bioretention systems less than 100m^2 in area: $225 - 275/m^2 including vegetation.
- Swale bioretention systems: $100 - 120/linear metre including vegetation (for this system the filter zone has a width of 1m and the swale has a top width of 3-4m).

The Centre for Watershed Protection (CWP, 1998) and US EPA (2001) reported the typical annual maintenance cost ≈ 5-7% of the construction cost.

Fletcher *et al.* (2003) suggested that a grassed bioretention system forming part of a residential nature strip costs ~$135 per linear metre to construct (based on costings from the Lynbrook Estate in SE Melbourne). The suggested maintenance cost for mature systems is reportedly similar to that of swales ~$2.50/m^2 for grassed systems and ~$1.50/m^2 for vegetated systems using native vegetation.

URS (2003) estimated unit rates for the construction of 3m wide, 1m deep bioretention trenches as $410/m or $137/m^2 of surface area. This estimate included: excavation and installation of geofabric liner, drainage pipe, drainage layer, filter media, sand, top-soil and vegetation.

A unit cost of $350 per linear metre was used for the construction of a road-side bioretention system during a desk-top water sensitive urban design project in the Snowy Monaro region (Lane, 2004).

Boubli and Kassim (2003) reported quotes supplied by three tenderers for the Heritage Mews project in Sydney for 'biofiltration trenches' as being approximately $150/m^3 of trench. This estimate *excludes* costs associated with plants and landscaping.

Taylor (2005) used Australian costing data from bioretention systems and swales (i.e. combined data) to estimate, the:

- Total construction cost (TC) for bioretention systems and swales ≈ 85% of total acquisition cost (TAC).
- Typical annual maintenance cost ≈ 4.3% of total acquisition cost.
- Renewal / Adaptation cost ≈ 2.0% of total acquisition cost (per annum).
- Decommissioning costs ≈ 39% of total acquisition cost.

Taylor (2005) also used bioretention system and swale costing data from around Australia to estimate various BMP size / cost relationships. These relationships have been built into the life cycle costing module in the CRC's MUSIC model and are documented in the User Manual for Version 3 of MUSIC. Estimates and algorithms address:

- Total acquisition cost as a function of the surface area of the treatment zone.
- Typical annual maintenance cost, as a function of the surface area of the treatment zone (for bioretention systems only) or total acquisition cost (for bioretention systems and swales).
- Renewal / Adaptation cost and renewal period (i.e. infrequent maintenance events that involve an alteration to the design or replacement of parts of the BMP) as a function of total acquisition cost.
- Decommissioning cost as a function of total acquisition cost.
- Life cycle.

SAND FILTERS

The Centre for Watershed Protection (CWP, 1998) and US EPA (2001) reported in Taylor and Wong (2002): Annual maintenance cost ≈ 11-13% of construction cost.

WBM (2003) estimated costs for supply and installation as $5,000 to $50,000 (cited in URS, 2003). Maintenance costs were estimated to range from $1,000 to $5,000 p.a. depending on the scale of the device.

Gibbs (2003) reported that a sand filter and storage basin in Sydney with a catchment area of 60,000m^2, a sand filter size of 32m^2, and a 'storage plus filter area' of 150m^2 cost $167,815 to construct (i.e. $1,500 per m^2 of sand filter including storage capacity).

Newcastle City Council (2002) reported that the construction cost (in 2001 Australian dollars) for a sand filter that treated a catchment approximately 5,000m^2 in size was $28,004 (or $36,153 including site establishment, survey, design and supervision costs).

SEDIMENT TRAPS / BASINS

Weber (2001 and 2002) reported in Taylor and Wong (2002): Typical annual maintenance cost ≈ 6% of construction cost. Also, typical construction cost ≈ $50,000 and typical annual maintenance cost ≈ $2,800.

Taylor (2005) used Australian costing data to estimate that for "sediment basins and ponds", the:

- Renewal / Adaptation cost ≈ 1.4% of total acquisition cost (per annum).

- Decommissioning costs ≈ 38% of total acquisition cost.

Taylor (2005) also used sediment basin and pond costing data from around Australia to estimate various BMP size / cost relationships. These relationships have been built into the life cycle costing module in the CRC's MUSIC model and are documented in the User Manual for Version 3 of MUSIC. Estimates and algorithms address:

- Total acquisition cost as a function of basin / pond area.
- Typical annual maintenance cost as a function of the average annual volume of removed material or area of the basin / pond.
- Renewal / Adaptation cost and renewal period (i.e. infrequent maintenance events that involve an alteration to the design or replacement of parts of the BMP) as a function of total acquisition cost.
- Decommissioning cost as a function of total acquisition cost.
- Life cycle.

PONDS

See comments above for sediment basins (i.e. costings prepared by Taylor, 2005).

The Centre for Watershed Protection (CWP, 1998) and US EPA (2001) reported typical annual maintenance cost ≈ 3-6% of construction cost.

Fletcher *et al.* (2003) suggested that a rough estimate for pond construction cost (based only on 1 case study) is ~$2,000/ha of catchment.

Weber (2002) reported typical construction cost ≈ $30,000/ML of pond volume (based on limited data).

Walsh (2001) reported typical construction cost ≈ $60,000/ha of pond area (base cost).

RAINWATER TANKS

Kuczera and Coombes (2001) reported that the typical annual maintenance cost ≈ $70 for above ground tanks.

Gardner *et al.* (2003) reported that operation and maintenance costs for a 22kL tank on the Gold Coast, where water was used for toilet flushing and garden watering, were $101.43/year (i.e. $66.43 for electricity and $35 for maintenance). Water savings from the use of the tank (for a detached residential development) was 124kL/year or $136.40/year in avoided costs (or mains water). The purchase and installation cost was $2,600 (this includes a 1 kw pump and plumbing costs).

An estimate of rainwater tank pump electricity use is 3,000kwh/ML (T. Gardner, pers. comm., 2004). This equates to a cost of approximately $410.40/ML (using the electricity cost provided by Grant and Hallmann, 2003).

Cardno BLH (2002) reported additional costs associated with above ground steel tanks from 2 NSW case studies (i.e. the Heritage Mews and Pioneer Street Projects):

- The associated cost to reticulate separate supply to toilets ≈ $400 (for 1 WC connection) for 1.5kL tanks; $800 (for 2 WCs) for 3, 4 and 5kL tanks; and $1,050 (for 3 WCs) for 9 and 10kL tanks.

In addition, URS (2003) estimated the on-going cost of running an electric pump associated with water tanks that are plumbed into a house (e.g. for toilet flushing) would be $150 p.a. It is assumed that this estimate includes pump maintenance as well as electricity.

Boubli and Kassim (2003) reported the following plumbing costs associated with aboveground tanks for a development in Sydney's north-west:

- Supply pump: $350.
- Install tank including pipe work, fittings and slab: $750.
- Install pump including electrics and soundproof enclosure: $470
- Cost to reticulate separate supply for toilet flushing at one ground floor and two first-floor toilets: $1,050.
- Total: $2,620.

The Institute for Sustainable Futures (2002) reported estimated costs for additional plumbing that would be required to supply treated stormwater for toilet flushing at the Kogarah Town Square Redevelopment Project as $350 per apartment.

Lane (2004) estimated the cost of *retrofitting* rainwater tanks to existing residential properties using three case studies in Snowy Monaro region. The conclusion of this work was that a total of $3,000 to $4,000 would be adequate to fully retrofit a 9kL above ground rainwater tank. This cost included purchase and supply of the tank (the average cost was approximately $1,288), the purchase of the pump (the average cost was approximately $577), plumbing materials (the average cost was approximately $1,010), the plumbing labour (varied greatly from $580 to $3,807) and the cost of the electrician (the average cost was approximately $187).

Coombes (2002) estimated typical rainwater tank supply costs: Aquaplate = $540 (4.5kL) and $860 (9kL); Galvanised iron $440 (4.5kL) and $640 (9kL); Polymer $670 (4.5kL) and $1,150 (9kL); and Concrete $1,300 (4.5kL) and $1,800 (9kL). Note that up-to-date purchase prices for tanks are readily available from suppliers, many of whom have web sites. The typical installation cost for 5-10kL tanks was estimated by Coombes (2002) to be $1,600 (estimate includes pump, pressure controller, stand, fittings including float system and installation).

SIA (2004) reported the following cost estimates associated with Aquaplate above ground tanks:

Item	Approximate cost for each tank size (in $2001)		
	5 kL	10 kL	15 kL
Aquaplate rainwater tank	540	870	1,200
Pump + pressure controller	200 + 160	200 + 160	200 + 160
Plumber and fittings	500	500	500
Float system	100	100	100
Concrete base	200	200	200
GST (10%)	170	200	240
Total (incl. GST)	**$1,910**	**$2,230**	**$2,600**

In addition, SIA (2004) reported that:

- pumps typically have a 10 year life span; and
- the operating and maintenance cost of pumps are approximately $0.1 per kL of rainwater consumed. (Note that a typical family home may use ~20kL/year of water for toilet flushing.)

Boubli and Kassim (2003) reported the following cost estimates for supply and installation of above and below ground rainwater tanks or a single installation in Sydney:

Tank size	Tank type	Tank shape	Approximate tank supply cost
1.5kL	Galvanised steel, aboveground	Round Rectangular / ovular	$2,470 $2,870
	Colourbond finish with a polymer type liner, aboveground	Round Rectangular / ovular	$2,570 $2,970
3kL	Galvanised steel, aboveground	Round Rectangular / ovular	$2,970 $3,470
	Colourbond finish with a polymer type liner, aboveground	Round Rectangular / ovular	$3,320 $3,820
5kL	Galvanised steel, aboveground	Round Rectangular / ovular	$3,170 $4,280
	Colourbond finish with a polymer type liner, aboveground	Round Rectangular / ovular	$3,620 $4,600
9kL	Galvanised steel, aboveground	Round	$3670
	Colourbond finish with a polymer type liner, aboveground	Round	$4,120
5kL	Below ground (Rocla Eco Rain)	-	$7,800 (plus $800 for reticulation to toilets)
10kL	Below ground (Rocla Eco Rain)	-	$11,050 (plus $1,050 for reticulation to toilets)

Indicative prices for polyethylene (plastic) rainwater tanks are summarised below (Irrigation Warehouse, 2005). These prices include GST, typically include delivery and are relevant to New South Wales, Victoria, southern Queensland and the Australian Capital Territory.

Tank size (L)	Tank type	Approximate tank supply cost ($)
509	Slim line (aboveground)	$491
700	Tall round (aboveground)	$418
720	Slim (aboveground)	$501
758	Round (aboveground)	$511
1,074	Slim (aboveground)	$766
1,179	Round (aboveground)	$521
1,250	Round (aboveground)	$550
1,400	Tall slim (aboveground)	$792
1,615	Round (aboveground)	$551
1,800	Under house (aboveground)	$1,122
2,100	Tall slim (aboveground)	$1,144
2,281	Slim (aboveground)	$1,271
2,499	Squat (aboveground)	$601
2,500	Round (aboveground)	$682
2,500	Twin under-deck (aboveground)	$1,122
2,542	Tall (aboveground)	$601
2,800	Tall slim (aboveground)	$1,496
3,600	Twin rectangular under house (aboveground)	$2,244
4,125	Squat (aboveground)	$901
4,885	Medium round (aboveground)	$901
5,000	Round (aboveground)	$968
9,000	RT poly tank (aboveground)	$1,595
9,609	Large squat (aboveground)	$1,850
10,478	Large tall (aboveground)	$1,500
10,500	RT poly tank (aboveground)	$1,705
13,500	RT poly tank (aboveground)	$2,024
15,064	Large (aboveground)	$1,850
22,500	Low profile (aboveground)	$2,376
22,500	RT poly tank (aboveground)	$2,640
24,180	Large tall (aboveground)	$2,551
25,090	Large low profile (aboveground)	$2,551
29,560	Very large (aboveground)	$2,950
38,334	Very large (aboveground)	$4,170
47,950	Monster (aboveground)	$5,152

Grant and Hallmann (2003) estimated the costs associated with a 2,250 litre plastic tank with a life span of 30 years as: $510 purchase; $38.50 (delivery); $270 (for plumbing costs that allow toilet flushing and garden watering to use tank water); $350 (for the pump); $100 (electrician costs). They also assumed the pump would last for 15 years, and the cost of running the pump (in Melbourne) was estimated to be $0.1368/kwh.

Taylor (2005) estimated a typical decommissioning cost for metal above ground tanks ≈ $200 and a life cycle of ~25 years (drawing upon estimates by Melbourne Water, 2003b).

Taylor (2005) also used rainwater tank costing data from around Australia to estimate various BMP size / cost relationships. These relationships have been built into the life cycle costing module in the CRC's MUSIC model and are documented in the User Manual for Version 3 of MUSIC. Estimates and algorithms address:

- Total acquisition cost including plumbing costs (as a function of above ground tank volume for 1 to 15 kL galvanized, colourbond, zincalume and aquaplate aboveground tanks of various shapes).
- Typical annual maintenance cost.
- Decommissioning cost.
- Life cycle.

ADDITIONAL COSTS AND COST BREAK-DOWNS

Melbourne Water (2003a) add 15% to estimated greenfield construction costs for "engineering fees" and 20% for "contingencies".

Brisbane City Council (2003) used the following assumption to break down total BMP construction costs where itemised costs were not available: 10% for design, 85% for construction and 5% for management costs.

Choi and Engel (2003) estimated that design costs for structural BMPs typically account for 30% of construction costs.

The Washington State Department of Transportation (2002) add 25% onto estimated BMP construction costs for "contingency" costs, 30% for "engineering services and permitting fees", and 10% for "mobilisation and demobilisation of equipment".

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